DOCUMENT RESUME

ED 464 216 CE 083 118

AUTHOR	Barbieri, Dave; Miller, Roger; Kellum, Mary
TITLE	Diesel Technology: Engines. Second Edition. Teacher Edition [and] Student Edition.
INSTITUTION	Multistate Academic and Vocational Curriculum Consortium, Stillwater, OK.
PUB DATE	2002-00-00
NOTE	1119p.; For the earlier edition "Diesel Fundamentals" (1988), see ED 318 922.
AVAILABLE FROM	Multistate Academic and Vocational Curriculum Consortium, 1500 West Seventh Avenue, Stillwater, OK 74074 (Teacher edition: order no. 203601, $131.50; Student edition: order no. 203602, $70.50). Tel: 800-654-3988 (Toll Free); e-mail: mavccweb@okcareertech.org; Web site: http://www.mavcc.org.
PUB TYPE	Guides - Classroom - Learner (051) -- Guides - Classroom - Teacher (052)
EDRS PRICE	EDRS Price MF08 Plus Postage. PC Not Available from EDRS.
DESCRIPTORS	*Auto Mechanics; Behavioral Objectives; *Curriculum Guides; *Diesel Engines; *Fuels; Instructional Materials; Learning Activities; *Maintenance; Postsecondary Education; Secondary Education; Teaching Guides; *Technical Occupations; Technology Education; Tests; Troubleshooting; Units of Study
IDENTIFIERS	Crosswalks (Linking); Fuel Systems; National Automotive Technicians Educ Foundation; National Institute Automotive Service Excellence; *Trucks

ABSTRACT

This diesel technology series offers secondary and postsecondary students an opportunity for learning required skills in the diesel industry. It aligns with the medium/heavy duty truck task list developed by the National Automotive Technicians Education Foundation and used by the National Institute for Automotive Service Excellence in certification of medium/heavy duty truck technicians. The teacher edition consists of introductory pages, teacher pages, and the student edition. Introductory pages include training and competency profile; national skills and/or state duty/task crosswalk; instructional/task analysis; basic skills icons and classifications; basic skills matrix; and tools, equipment, and materials list. Teacher pages include some or all of the following: unit contents (teacher and student components); suggested activities; answers to assignment sheets; written test with key; learning activities sheet; teacher supplements; and transparency masters. The student edition contains some or all of these elements: unit contents; objective sheet; information sheet; student supplements; assignment sheets; and job sheets. The 17 units are divided into these 4 sections: introduction to engine principles and procedures; engine systems and components; fuel systems; and engine diagnosis and maintenance. (YLB)

Reproductions supplied by EDRS are the best that can be made
from the original document.

ED 464 216

Diesel Technology: Engines
Teacher Edition
[and]
Student Edition

Dave Barbieri, Roger Miller, and Mary Kellum

U.S. DEPARTMENT OF EDUCATION
Office of Educational Research and Improvement
EDUCATIONAL RESOURCES
INFORMATION CENTER (ERIC)

☐ This document has been reproduced as received from the person or organization originating it.

☐ Minor changes have been made to improve reproduction quality.

- Points of view or opinions stated in this document do not necessarily represent official OERI position or policy.

PERMISSION TO REPRODUCE AND
DISSEMINATE THIS MATERIAL
IN MICROFICHE ONLY HAS BEEN
GRANTED BY

A. Pratt

TO THE EDUCATIONAL RESOURCES
INFORMATION CENTER (ERIC)

2B

CE 083 118

BEST COPY AVAILABLE

Diesel Technology
Engines

Second Edition

CE083118

Teacher Edition

02-015632 20360

BEST COPY AVAILABLE

Diesel Technology: Engines

Second Edition

Teacher Edition

Written by

Dave Barbieri
Roger Miller
Mary Kellum

Project coordinated by

Mary Kellum
Instructional Development Specialist

Developed by

The Multistate Academic and Vocational Curriculum Consortium, Inc.

Board of Directors

Kimberly Sadler, Oklahoma, Chair
Ben Clay, Kansas, Vice Chair
John Davidson, Arkansas, Parliamentarian
Shirley Gant, Georgia
Jim Fliehler, Iowa
Connie Buck, Louisiana
Roberta Brown, Pennsylvania
Larry Nelson, South Dakota
Lynne Cohen, Tennessee
Esther Camacho, Texas

Jane Huston, Executive Director

02-015632

203601

©2002 by the Multistate Academic and Vocational Curriculum Consortium, Inc.

All rights reserved. No part of this book may be reproduced in any form or by any means without written permission from the publisher unless otherwise specified.

Printed in the United States of America by the
Oklahoma Department of Career and Technology Education
Stillwater, OK 74074-4364

For more information, contact the
Multistate Academic and Vocational Curriculum Consortium
1500 West Seventh Avenue
Stillwater, OK 74074-4364

E-mail: mavccweb@careertech.org
Internet: http://www.mavcc.org
Phone: (800)654-3988 or (405)743-5578

The Multistate Academic and Vocational Curriculum Consortium does not discriminate on the basis of race, creed, color, national origin, sex, age, religion, veteran status, or qualified handicap.

Table of Contents

Introductory Pages

Foreword v
Acknowledgments vii
Use of this publication ix
Training and competency profile xvii
NATEF crosswalk xxi
Instructional/task analysis xxix
Basic skills icons and classifications xxxix
Basic skills matrix lv
Tools, equipment, and materials list xcvii

Units of Instruction

Section A: Introduction to Engine Principles and Procedures

Unit 1–A: Engine Operating Principles

Unit 2–A: Disassembly Procedures and Analysis

Section B: Engine Systems and Components

Unit 1–B: Lubrication Systems

Unit 2–B: Cooling Systems

Unit 3–B: Cylinder Blocks and Liners

Unit 4–B: Crankshafts and Bearings

Unit 5–B: Pistons and Connecting Rods

Unit 6–B: Camshafts, Trains, and Timing

Unit 7–B: Cylinder Head Assemblies

Unit 8–B: Air Induction and Exhaust

Unit 9–B: Engine Brakes and Retarders

Section C: Fuel Systems

Unit 1–C: Basic Fuel Systems and Components

Unit 2–C: Mechanical Fuel Injection Diagnosis and Repair

Unit 3–C: Electronic Fuel Injection Diagnosis and Repair

Unit 4–C: Emissions

Section D: Engine Diagnosis and Maintenance

Unit 1–D: General Engine Diagnosis

Unit 2–D: Preventive Maintenance and Tune-Up

7

Foreword

When MAVCC began the process for revising its diesel mechanics series, we wanted to develop a set of instructional materials that would provide students with the cognitive (knowing), psychomotor (doing), and affective (attitude) skills necessary to be successful in the diesel trade and that would address the emerging technology in the field. With the help of extremely qualified teachers, industry representatives, and writers, our new diesel technology series offers secondary and postsecondary students an excellent opportunity for learning required skills in the diesel industry.

The series aligns with the medium/heavy duty truck task list developed by the National Automotive Technicians Education Foundation (NATEF) and used by the National Institute for Automotive Service Excellence (ASE) in the certification of medium/heavy duty truck technicians. Each publication will include a matrix showing where the NATEF tasks are being sought.

The new publications will also reflect those tasks identified by MAVCC's technical committee which were not covered in the NATEF task list, especially those dealing with the maintenance and repair of diesel-powered heavy equipment and agriculture equipment.

These instructional materials are designed for student use and to assist teachers in organizing and improving instruction. Their design is based on the curriculum alignment concept of first stating the objectives (objective sheet), developing instructional strategies for teaching to those objectives (information, assignment, and job sheets), and assessing to those same objectives (criterion-referenced evaluation instruments).

A chart which classifies and defines each of the academic and workplace skills and competencies has been included in the teacher edition and reflects key elements from *What Work Requires of Schools: A SCANS Report for America 2000*, a 1991 study by the U.S. Department of Labor; *Workplace Basics: The Skills Employers Want*, a three-year study conducted jointly by the American Society for Training and Development (ASTD) and the United States Department of Labor (DOL); and other national and state sources. These tools have been provided in an effort to help educators identify and document where basic academic and workplace skills are being taught. By reinforcing these skills, the teacher should assist student in improving their employability skills.

Special attention should be given to the matrix identifying basic academic and workplace skills being reinforced in these instructional materials as well as the teacher suggestions on ways to reinforce these skills found in the teacher pages for each unit.

As you use these instructional materials, we hope that you will find that they contribute to the quality of your program. If any problems occur or if you have any suggestions for improvement of the materials, please call or write us.

Kimberly Sadler, Chair
MAVCC Board of Directors

Jane Huston
MAVCC Executive Director

Acknowledgments

Appreciation is extended to the many individuals who contributed their time and talent to the development of Diesel Technology: Engines.

The content of this publication was planned by the following members of the MAVCC diesel revision committee:

Dave Barbieri, instructor
Lee High School
Tyler/Overton, TX

Jerry Bisbee, dealer trainer
Oklahoma City Freightliner, Inc.
Oklahoma City

Lane Eichhorn, instructor
Parkland College
Champaign, IL

Danny Fisher, instructor
Pulaski Technical College
North Little Rock, AR

Mike Foster, training manager
Cummins Southern Plains
Arlington, TX

John R. Harris, retired instructor
Panora, IA

David Kennedy, instructor
T.H. Harris Technical Institute

Phil Lanham, owner
DEL Co Diesel
Oklahoma City, OK

Orville Manuel, automotive program specialist
Oklahoma Department of Career and Technology Education
Stillwater, OK

Roger Miller, retired instructor and owner of Diesel Fuel Injection Service
Salina, KS

Terry Scarberry, instructor
Gordon Cooper Technology Center
Shawnee, OK

Greg Tatro, Detroit Diesel trainer
United Engines
Oklahoma City, OK

Carl Tesch, instructor
Lake Area Technical Institute
Watertown, SD

Larry Wright, service development manager
DARR Equipment
Dallas Texas

Appreciation is also extended to the original writers of MAVCC's Diesel Fundamentals (©1988) upon which much of this information is based. Thank you Elton Clark, Joe Mathis, and Tom Sprinkle.

Special appreciation is extended to Rick Lomenick for his excellent work as the electronic publishing technician on this publication.

Appreciation is extended to the Graphics Division of the Oklahoma Department of Career and Technology Education for the artwork and printing of this text.

Use of This Publication

Diesel Technology: Engines is available in both a teacher and student edition. The contents of these materials are tied to measurable and observable learning outcomes that were identified and validated by the diesel advisory committee, comprised of business/industry representatives and teachers. Competencies align with the Medium/Heavy Truck Program Standards developed by the National Automotive Technician's Education Foundation (NATEF) in conjunction with the National Institute for Automotive Service Excellence (ASE).

Teacher Edition

The complete teacher edition consists of introductory pages, teacher pages, and the student edition. Materials are loose-leaf and three-hole punched and are divided into units of instruction that may be broken into more than one lesson or class period. For added flexibility, each unit is individually numbered beginning with a T for teacher page, followed by the unit number and page number.

Example:

Page 17 of Unit 3 in the teacher pages is represented as T 3–17.

MAVCC—*Diesel Technology: Engines* T 3–17

Page 1 of Unit 5 in the teacher pages is represented as T 5–1.

MAVCC—*Diesel Technology: Engines* T 5–1

Pages in the student edition are numbered beginning with the unit number, followed by the page number.

Example:

Page 7 of Unit 5 in the student edition is represented as Page 5–7.

MAVCC *Diesel Technology: Engines* Page 5—7

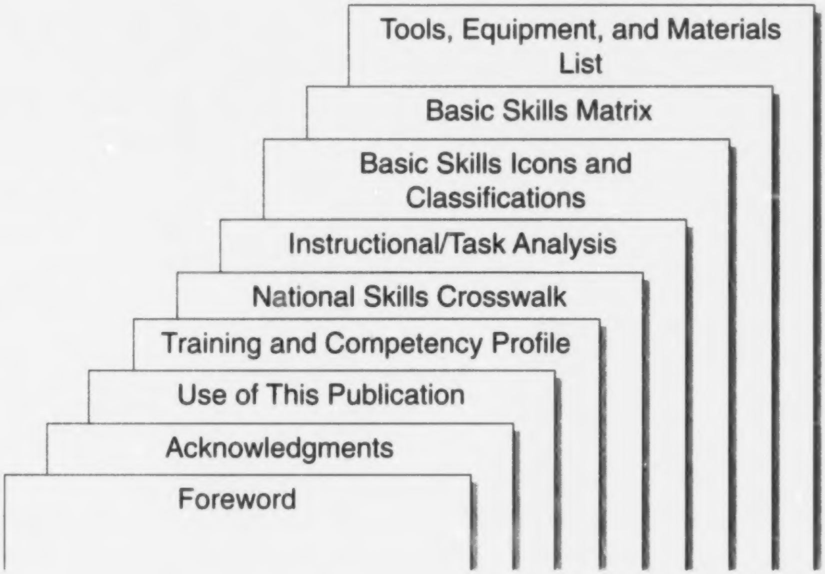
Use of This Publication

For group instruction, the teacher should determine the best way to teach each objective and allow for student participation. For self-paced or individualized instruction, students should be provided with opportunities to become involved in planning and being responsible for their own education. Careful study of each unit of instruction by the teacher will help to determine the following:

- amount of material that can be covered in each class period;
- supplies and materials required for assignment sheets and job sheets;
- resource people who must be contacted;
- supplementary materials to be ordered;
- skills that must be demonstrated and the amount of class time needed for demonstrations; and
- amount of class time needed for student practice and return demonstrations of mastered skills.

Teachers are encouraged to localize and personalize these materials to meet the needs of individual students, the community, and prospective employers.

Introductory Pages


Tools, Equipment, and Materials List
Basic Skills Matrix
Basic Skills Icons and Classifications
Instructional/Task Analysis
National Skills Crosswalk
Training and Competency Profile
Use of This Publication
Acknowledgments
Foreword

Use of This Publication

In addition to general information, such as the table of contents, acknowledgments, and the use of this publication, the following tools have been provided to assist administrators and teachers in planning for instruction.

☐ **Training and Competency Profile.** This form may be copied and used to record information about each student, such as enrollment dates, class attendance, and work experience, and to document the student's mastery of specific job competencies. It can also be used to provide information about the student's qualifications to potential employers and/or for entry into advanced training programs.

☐ **National Skills and/or State Duty/Task Crosswalk.** This document identifies the national and/or state skill standards covered in this publication and lists specifically where these skills are located by unit number and objective.

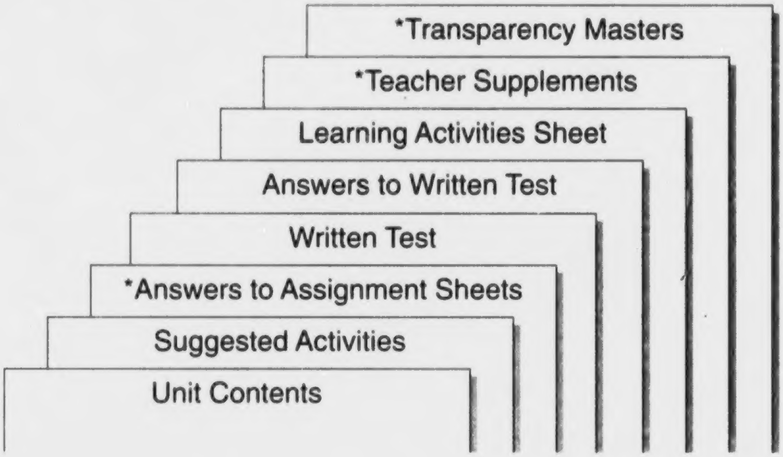
☐ **Instructional/Task Analysis.** This document provides a quick review of the contents of this publication by identifying the cognitive skills (what the student should know) and psychomotor skills (what the student should be able to do) addressed in each unit of instruction.

☐ **Basic Skills Icons and Classifications.** This page provides a reference guide of the graphic symbols that are used to identify the basic academic and workplace skills included in each focus assignment, assignment sheet, and job sheet.

☐ **Basic Skills Matrix.** This document graphically summarizes the academic and workplace skills training included in the instructional materials, unit by unit. It should be helpful to teachers in planning for instruction, and to administrators as documentation that basic skills are being taught as part of the vocational training.

☐ **Tools, Equipment, and Materials List.** This document provides a comprehensive list of those items needed in a vocational program for students to complete training. It also can assist administrators and teachers in determining program costs.

Teacher Pages


*Transparency Masters
*Teacher Supplements
Learning Activities Sheet
Answers to Written Test
Written Test
*Answers to Assignment Sheets
Suggested Activities
Unit Contents

*Designates components that may not appear in every unit of instruction

Teachers should study the teacher and student pages before introducing the unit, allowing enough time to obtain supplemental materials and to contact outside resource persons.

☐ **Suggested Activities.** This component assists teachers during the preparation stage of the teaching/learning process by providing an instructional plan, teaching suggestions, a list of references used in the development of each unit, and a list of suggested supplemental resources (books, posters, pamphlets, videotapes, computer software, and Internet sites) that may be used to enhance instruction.

Instructions for evaluating student performance on the assignment sheets and job sheets are also included in the suggested activities section. Teachers should select and discuss with students the rating scale that will be used.

☐ **Answers to Assignment Sheets.** An answer key is provided, when applicable, to assist the teacher in evaluating student performance on a given assignment.

☐ **Written Test.** This component provides criterion-referenced evaluation of every cognitive objective listed in the unit of instruction, and serves as both a pretest and posttest to assist teachers in measuring each student's competency gains. (Assignment sheet and job sheet objectives are not evaluated on the written test.) If the teacher has added, deleted, or modified any objectives, appropriate changes should be made to both the test and answers to the written test.

Tests may be divided into shorter tests covering three or four objectives at a time and given soon after those objectives have been covered. A selection of test items from the units covered may be used for a final test at the end of each term if desired. The written test is included in the teacher edition only and should be duplicated for student use.

☐ **Answers to Written Test.** An answer key is provided to assist the teacher in evaluating student performance on the written test.

☐ **Learning Activities Sheet.** This component provides a model for teachers to use in implementing a self-paced or individualized program, and guides the student through the required components in the student edition (objective sheet, information sheet, student supplements, assignment sheets, and job sheets). The teacher should modify the learning steps as needed to incorporate resources available in the classroom (videotapes, computer software, magazines, etc.) and to address instructional strategies that may be needed to enhance learning for each student. Final copies should be distributed for student use.

The following icons will be used on the learning activities sheet to denote steps that require additional resources:

📖 Read a book, magazine, or journal article

💻 Use a CBT program or other software application

WWW Access a site on the World Wide Web

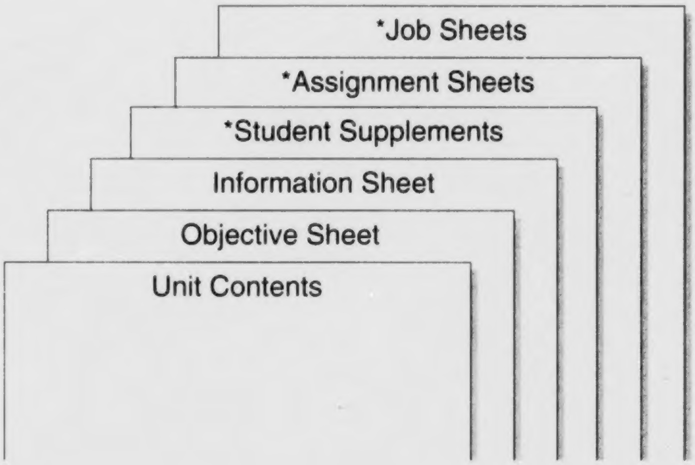
🖥 Look at PowerPoint® or other computer presentation

📼 Watch a videotape

☐ **Teacher Supplements.** These are optional materials for the teacher to use. They have three purposes: to provide the teacher with higher-level materials to stretch the advanced student; with remedial information or practice to assist the less-advanced student; and with state-of-the-art information in which the teacher may not have a background or with information that is not readily available in other books. Some teacher supplements may be duplicated for student use and are marked accordingly.

☐ **Transparency Masters.** These overheads are used to direct the students' attention to the topic of classroom discussion. Transparencies allow the student to see as well as hear the information being presented, thus reinforcing the learning process. They may provide illustrations, charts, schematics, or additional information needed to clarify and reinforce objectives included in the unit of instruction. Some of these items may also appear with the appropriate objectives in the information sheet in the student edition. The teacher may make acetate copies from the masters or, in most cases, complete transparency sets are available for purchase.

Student Edition



*Designates components that may not appear in every unit of instruction

For best results, students should be provided with a copy of the student edition and should be allowed to take notes in the margins as additional information is provided by the instructor or as the student acquires additional information through library or Internet research.

☐ **Objective Sheet.** This component summarizes each unit for the student and teacher. The objective sheet is based on established performance objectives that state the goals for successful completion of a unit of instruction. Objectives are stated in two forms: unit objectives that state the expected performance of each student after completion of the unit and specific (enabling) objectives that state what the student must be able to do to reach the unit objective.

The objectives should be stressed throughout the teaching/learning process. This will help answer any questions concerning performance requirements for each instructional unit. The objectives can also help determine teaching strategies and instructional methods.

Teachers should modify, delete, or add objectives in order to meet the needs of the students and community. When objectives are added, the teacher should remember to supply the needed information, assignment and/or job sheets, and criterion-referenced test items to cover the new objectives.

☐ **Information Sheet.** This component provides the student with the essential information for meeting the cognitive objectives in the unit. Teachers will find that the information sheet serves as an excellent guide for presenting background knowledge necessary to develop the skills specified in the unit objective. Students should read the information sheet before the information is discussed in class. Space is provided in the margins for students and teachers to add notes that clarify and/or expand upon the information presented.

☐ **Student Supplements.** This component is included in a unit of instruction when additional information is needed in order for students to complete one or more of the assignment and/or job sheets. Students are not directly tested over the information presented in a supplement; however, their ability to apply this information may be evaluated in the completion of assignment and/or job sheets.

☐ **Assignment Sheets.** The assignment sheets address the learning levels at or above the application level of Bloom's taxonomy. They provide students with an opportunity to use higher-order thinking skills, such as problem solving, synthesizing, analyzing, and evaluating. In addition, they may provide additional opportunities for students to develop their language skills.

Assignment sheets can be paper-and-pencil activities, as well as those using computer software, videotapes, models, handouts, or other resources as appropriate. Criteria are provided to evaluate student performance objectively.

☐ **Job Sheets.** Job sheets are designed as skill tests and give the instructor direction as to the psychomotor skills to be taught, and provide the criteria to evaluate student performance objectively. They also help provide potential employers with a picture of the skills being taught during training and the performances that might be reasonably expected from an individual who has completed the training.

The teacher should provide students with a copy of each job sheet and/or the procedure's manual and/or job specifications when necessary. The teacher should also discuss the equipment and materials that will be needed for the job and the criteria that will be used to evaluate the student's performance, and demonstrate the procedure prior to having students practice the procedure. Safety should be stressed as part of each demonstration.

When a student is ready to be evaluated, the teacher should follow the instructions for evaluating student performance which may be found in the suggested activities component of the teacher unit.

As you use these instructional materials we hope that you will find that they contribute to the quality of your program. If any problems occur or if you have any suggestions for improvement of the materials, please write us at 1500 West Seventh Avenue, Stillwater, OK 74074-4364, or E-mail us at mavcc@mavcc.com.

Training and Competency Profile

Student Information

Program ______________________ Instructor ______________________

Name ______________________ Soc. Sec. No. ______________________

Address ______________________ Phone ______________________

Grade ______________ School ______________________

Allergies/Disabilities that might require special accommodation for training (please specify)

____

In case of emergency, contact ______________________ Phone ______________

Record of Enrollment

Date of Enrollment ____- ____- ____ Total Class Hours________ Total Hours Absent________

Date of Withdrawal ____- ____- ____ Total On-the-Job Training Hours________ Total Hours Tardy________

Date of Completion ____- ____- ____ Total Lab Hours__________

On-the-Job Training/Work Experience

______________________ ______________________

Place of Employment Address

______________________ ______________________

Supervisor's Name Phone

______________________ ______________________

Duration of Employment Job Title

____

Job Responsibilities

______________________ ______________________

Place of Employment Address

______________________ ______________________

Supervisor's Name Phone

______________________ ______________________

Duration of Employment Job Title

____

Job Responsibilities

Training and Competency Profile

Student Evaluation

Directions: Evaluate the student using the rating scale below. Write the appropriate number to indicate the degree of competency achieved. The descriptions associated with each of the numbers focuses on a level of student performance for each of the tasks listed. The written test scoreline is provided for optional teacher use. It may not be applicable in all cases.

Rating Scale: Option A

4	Skilled—Can perform job with no additional training
3	Moderately Skilled—Has performed job during training program; limited additional training may be required.
2	Limited Skill—Has performed job during training program; additional training is required to develop skill.
1	Unskilled—Is familiar with process, but is unable to perform job.
0	No Exposure—No information or practice provided during training program, complete training required.
NA	Non-applicable.

Rating Scale: Option B

Yes—Can perform with no additional training
No—Is unable to perform satisfactorily

Unit 1–A: Engine Operating Principles

_______ 1. Identify companion cylinders.
_______ 2. Locate and record engine specifications.
_______ 3. Identify valve and piston position during each stroke.
_______ 4. Locate TDC for #1 piston.
_______ 5. Measure bore and stroke and compute engine displacement.
_______ 6. _______________________________

_______ Written Test Scores
Pretest score ________%
Posttest score ________%

Unit 2–A: Disassembly Procedures and Analysis

_______ 1. Determine required tools for various tasks.
_______ 2. Evaluate worn engine components.
_______ 3. Determine possible causes of engine component failures.
_______ 4. Steam clean an engine.
_______ 5. Remove engine accessories and external lines.
_______ 6. Remove engine and mount on an engine stand.
_______ 7. Engine disassembly: Remove cylinder head.
_______ 8. Engine disassembly: Remove gear train and camshaft.
_______ 9. Engine disassembly: Remove pistons and connecting rods.
_______ 10. Engine disassembly: Remove cylinder liners.
_______ 11. Engine disassembly: Remove crankshaft.
_______ 12. _______________________________

_______ Written Test Scores
Pretest score ________%
Posttest score ________%

Unit 1–B: Lubrication Systems

_______ 1. Service and install oil pump and oil pump drive components.
_______ 2. Service and inspect lubrication system screens and pipes.
_______ 3. Service and inspect oil pressure regulator valve and bypass valve.
_______ 4. Service and inspect oil cooler and lines.
_______ 5. _______________________________

_______ Written Test Scores
Pretest score ________%
Posttest score ________%

Unit 2–B: Cooling Systems

_______ 1. Flush, refill, and bleed coolant system.
_______ 2. Inspect water pump, belts, and hoses.
_______ 3. Check operation of fan assembly and controls.
_______ 4. Test operation of thermostat installed in engine.
_______ 5. Test operation of thermostat on the bench.
_______ 6. Check operation and accuracy of temperature indicating system.
_______ 7. _______________________________

_______ Written Test Scores
Pretest score ________%
Posttest score ________%

Training and Competency Profile

Unit 3–B: Cylinder Blocks and Liners

________ 1. Pressure test a cylinder block.
________ 2. Disassemble and clean a cylinder block.
________ 3. Inspect a cylinder block.
________ 4. Install new camshaft bushings.
________ 5. Clean and inspect cylinder bores.
________ 6. Install cylinder liners and set liner protrusion.
________ 7. ________________________________

________ Written Test Scores
Pretest score ________%
Posttest score ________%

Unit 4–B: Crankshafts and Bearings

________ 1. Remove, clean, and inspect a crankshaft.
________ 2. Install main bearings and crankshaft.
________ 3. Perform an in-frame bearing roll-in.
________ 4. Inspect viscous vibration damper/harmonic balancer.
________ 5. Inspect bonded vibration damper/harmonic balancer.
________ 6. Inspect flywheel.
________ 7. ________________________________

________ Written Test Scores
Pretest score ________%
Posttest score ________%

Unit 5–B: Pistons and Connecting Rods

________ 1. Remove, disassemble, and inspect a piston and connecting rod assembly.
________ 2. Measure piston-to-cylinder wall clearance and ring end gap.
________ 3. Assemble and install piston and connecting rod assembly.
________ 4. ________________________________

________ Written Test Scores
Pretest score ________%
Posttest score ________%

Unit 6–B: Camshafts, Trains, and Timing

________ 1. Remove, clean, and inspect a camshaft.
________ 2. Remove, inspect, and install cam bushings.
________ 3. Install a camshaft and set cam ti[illegible]
________ 4. ________________________________

________ Written Test Scores
Pretest score ________%
Posttest score ________%

Unit 7–B: Cylinder Head Assemblies

________ 1. Locate and label intake and exhaust valves.
________ 2. Clean and inspect a cylinder head.
________ 3. Recondition a cylinder head.
________ 4. Install a cylinder head assembly and adjust valves.
________ 5. ________________________________

________ Written Test Scores
Pretest score ________%
Posttest score ________%

Unit 8–B: Air Induction and Exhaust Systems

________ 1. Inspect and test air/induction system.
________ 2. Inspect and service turbo/supercharger and related components.
________ 3. Clean and test jacket water intercooler.
________ 4. Clean and test air-to-air intercooler.
________ 5. Inspect and test exhaust system.
________ 6. Inspect starting preheater controls.
________ 7. Test starting fluid system and controls.
________ 8. ________________________________

________ Written Test Scores
Pretest score ________%
Posttest score ________%

Unit 9–B: Engine Brakes and Retarders

________ 1. Remove, inspect, install, and adjust a Jacobs Engine Brake.
________ 2. Check operation of a BrakeSaver®.
________ 3. Check operation of an exhaust brake.
________ 4. Remove, clean, and install an exhaust brake.
________ 5. Check operation of a driveline retarder.
________ 6. ________________________________

________ Written Test Scores
Pretest score ________%
Posttest score ________%

Unit 1–C: Basic Fuel Systems and Components

________ 1. Trace fuel flow through basic fuel systems.
________ 2. Check fuel level, quality, and consumption.
________ 3. Inspect and service basic fuel supply components.
________ 4. ________________________________

________ Written Test Scores
Pretest score ________%
Posttest score ________%

Training and Competency Profile

Unit 2–C: Mechanical Fuel Injection Diagnosis and Repair

_______ 1. Isolate, remove, test, rebuild or replace, and reinstall injection nozzles.
_______ 2. Isolate, remove, test, and reinstall or replace mechanical unit injectors.
_______ 3. Inspect, test, adjust, and time a distributor-type (rotary) injection pump; determine needed repairs.
_______ 4. Inspect, test, adjust, and time an in-line injection pump; determine needed repairs.
_______ 5. Inspect, test, and adjust a PT injection pump and time the injectors; determine needed repairs.
_______ 6. _______________________________

_______ Written Test Scores
Pretest score ________%
Posttest score ________%

Unit 3–C: Electronic Fuel Injection Diagnosis and Repair

_______ 1. Inspect and test power and ground circuits and connections; determine needed repairs.
_______ 2. Check diagnostic trouble codes using electronic diagnostic equipment and technical information; determine needed repairs.
_______ 3. Inspect and replace electrical connectors, terminals, seals, and locks.
_______ 4. Access engine parameters; monitor or change as requested by customer.
_______ 5. Remove, inspect, and rebuild or replace a fuel transfer pump.
_______ 6. Remove, inspect, reinstall, and adjust electronic unit injectors; determine needed repairs.
_______ 7. _______________________________

_______ Written Test Scores
Pretest score ________%
Posttest score ________%

Unit 4–C: Emissions

_______ 1. Check vehicle for presence and operation of emission control devices.
_______ 2. Check vehicle for fuel type and appropriate application.
_______ 3. Test vehicle for excessive exhaust smoke.
_______ 4. Check vehicle for noise abatement devices.
_______ 5. _______________________________

_______ Written Test Scores
Pretest score ________%
Posttest score ________%

Unit 1–D: General Engine Diagnosis

_______ 1. Conduct an operator survey for engine diagnosis.
_______ 2. Interpret SAE code identifiers.
_______ 3. Check air intake system for restrictions.
_______ 4. Check exhaust back pressure.
_______ 5. Check crankcase pressure.
_______ 6. Check oil pressure.
_______ 7. Load test an engine with a dynamometer.
_______ 8. Locate a misfiring cylinder.
_______ 9. Locate an active fault code.
_______ 10. _______________________________

_______ Written Test Scores
Pretest score ________%
Posttest score ________%

Unit 2–D: Preventive Maintenance and Tune-Up

_______ 1. Determine maintenance needed for given situations.
_______ 2. Interpret maintenance troubleshooting charts.
_______ 3. Inspect engine coolant level and condition.
_______ 4. Pressure test coolant system and radiator cap.
_______ 5. Take oil sample, and change oil and filter(s).
_______ 6. Inspect and test indicator system components.
_______ 7. Perform a daily preventive maintenance check.
_______ 8. Perform a mileage preventive maintenance check.
_______ 9. Perform an engine tune-up.
_______ 10. _______________________________

_______ Written Test Scores
Pretest score ________%
Posttest score ________%

Permission to duplicate this profile is granted.

NATEF Crosswalk

The following NATEF Diesel Engines tasks (rev. 2001) are covered in this publication. The chart shows where each task is located within the publication. The first column identifies the NATEF task by name and number. The second column identifies the exact location by unit number and assignment sheet or job sheet number.

NATEF Tasks	MAVCC Tasks
II. Diesel Engines	
A. General Engine Diagnosis	
II. A. 1.—Inspect fuel, oil, and coolant levels and condition; determine needed actions.	Unit 1-C, Job Sheet 1—Check fuel level, quality, and consumption. Unit 2-D, Job Sheet 1—Inspect engine coolant level and condition. Unit 2-D, Job Sheet 5—Perform a daily preventive maintenance check.
II A. 2.—Diagnose causes of engine fuel, oil, coolant, air, and other leaks, determine needed action.	Unit 2-D, Job Sheet 5—Perform a daily preventive maintenance check. Unit 2-D, Job Sheet 6—Perform a mileage preventive maintenance check.
II. A. 3.—Interpret engine noises; determine needed action.	Unit 2-C, Job Sheet 1—Isolate, remove, test rebuild or replace, and reinstall injection nozzles. Unit 2-C, Job Sheet 2—Isolate, remove, test, and reinstall or replace mechanical unit injectors. Unit 1-D, Job Sheet 6—Locate a misfiring cylinder.
II. A. 4.—Observe engine exhaust smoke color and quantity; determine needed action.	Unit 4-C, Job Sheet 1—Test vehicle for excessive exhaust smoke.
II. A. 5.—Perform air intake system restriction and tests; determine needed action.	Unit 1-D, Job Sheet 1—Check air intake system for restrictions.
II. A. 6.—Perform intake manifold pressure (boost) test; determine needed action.	Unit 8-B, Job Sheet 1—Inspect and test air induction system.
II. A. 7.—Perform exhaust back pressure test; determine needed action.	Unit 1-D, Job Sheet 2—Check exhaust back pressure.
II. A. 8.—Perform crankcase pressure test; determine needed action.	Unit 1-D, Job Sheet 3—Check crankcase pressure.
II. A. 9.—Diagnose no cranking, cranks but fails to start, hard starting, and starts but does not continue to run problem; determine needed action.	Unit 2-D, Job Sheet 5—Perform a daily preventive maintenance check.
II. A. 10.—Diagnose surging, rough operation, misfiring, low power, slow deceleration, slow acceleration, and shutdown problems; determine needed action.	Unit 2-D, Job Sheet 5—Perform a daily preventive maintenance check.
II. A. 11.—Diagnose engine vibration problems; determine needed action.	Unit 2-D, Job Sheet 5—Perform a daily preventive maintenance check.
II. A. 12.—Check, record, and clear electronic diagnostic codes; monitor electronic data; determine needed action.	Unit 3-C, Job Sheet 2—Check diagnostic trouble codes using scan tools & technical information; determine needed repairs.

NATEF Crosswalk

NATEF Tasks	MAVCC Tasks
II. DIESEL ENGINES (cont.)	
B. Cylinder Head and Valve Train Diagnostic and Repair	
II. B. 1.—Remove, clean, inspect for visible damage, and replace cylinder head(s) assembly.	Unit 7-B, Job Sheet 1—Clean and inspect a cylinder head. Unit 7-B, Job Sheet 3—Install a cylinder head assembly and adjust valves.
II. B. 2.—Clean and inspect threaded holes, studs, and bolts for serviceability. Determine needed action.	Unit 7-B, Job Sheet 1—Clean and inspect a cylinder head.
II. B. 3.—Inspect cylinder head for cracks/damage; check mating surfaces for warpage; check condition of passages; inspect core and gallery plugs; determine needed action.	Unit 3-B, Job Sheet 1—Pressure test a cylinder block. Unit 3-B, Job Sheet 5—Clean and inspect cylinder bores. Unit 7-B, Job Sheet 1—Clean and inspect a cylinder head.
II. B. 4.—Disassemble head and inspect valves, guides, seats, springs, retainers, rotators, locks, and seals; determine needed action.	Unit 7-B, Job Sheet 2—Recondition a cylinder head. Unit 2-D, Job Sheet 7—Perform an engine tune-up.
II. B. 5.—Measure valve head height relative to deck, valve face-to-seat contact, and valve seat concentricity; determine needed action.	Unit 7-B, Job Sheet 2 Recondition a cylinder head. Unit 2-D, Job Sheet 7—Perform an engine tune-up.
II. B. 6.—Inspect injector sleeves and seals; measure injector tip or nozzle protrusion; perform needed action.	Unit 2-C, Job Sheet 1—Isolate, remove, test, rebuild or replace, and reinstall injection nozzles. Unit 3-C, Job Sheet 6—Remove, inspect, reinstall, and adjust electronic unit injectors; determine needed repairs. Unit 2-D, Job Sheet 7—Perform an engine tune-up.
II.B. 7.—Inspect and adjust valve bridges (crossheads) and guides; perform needed action.	Unit 7-B, Job Sheet 2—Recondition a cylinder head.
II. B. 8.—Reassemble cylinder head.	Unit 7-B, Job Sheet 3—Install a cylinder head assembly and adjust valves.
II. B. 9.—Inspect, measure, and replace/reinstall overhead camshaft; measure/adjust end play and backlash.	Unit 6-B, Job Sheet 1—Remove, clean, and inspect a camshaft. Unit 6-B, Job Sheet 3—Install a camshaft and set cam timing.
II. B. 10.—Inspect pushrods, rocker arms, rocker arm shafts, electronic wiring harness, and brackets for wear, bending, cracks, looseness, and blocked oil passages; perform needed action.	Unit 6-B, Job Sheet 1—Remove, clean, and inspect a camshaft.
II. B. 11.—Inspect cam followers; perform needed action.	Unit 6-B, Job Sheet 1—Remove, clean, and inspect a camshaft.

NATEF Tasks	MAVCC Tasks
II. DIESEL ENGINES (cont.)	
II. B. 12.—Adjust valve clearance as needed.	Unit 7-B, Job Sheet 3—Install a cylinder head assembly and adjust valves. Unit 2-C, Job Sheet 2—Isolate, remove, test, and reinstall or replace mechanical unit injectors. Unit 3-C, Job Sheet 6—Remove, inspect, reinstall, and adjust electronic unit injectors; determine needed repairs. Unit 2-D, Job Sheet 7—Perform an engine tune-up.
C. Engine Block Diagnosis and Repair	
II. C. 1.—Remove, inspect, service, and install pans, covers, vents, gaskets, seals, and wear rings.	Unit 1-C, Job. Sheet 2—Inspect and service basic fuel supply components.
II. C. 2.—Disassemble, clean, and inspect engine block for cracks/damage; measure mating surfaces for warpage; check condition of passages, core and gallery plugs; inspect threaded holes, studs, dowel pins, and bolts for serviceability; determine needed action.	Unit 3-B, Job Sheet 2—Disassemble and clean a cylinder block. Unit 3-B, Job Sheet 3—Inspect a cylinder block.
II. C. 3.—Inspect cylinder sleeve counterbore and lower bore; check bore distortion; determine needed action.	Unit 3-B, Job Sheet 5—Clean and inspect cylinder bores.
II. C. 4.—Clean, inspect, and measure cylinder walls or liners for wear and damage; determine needed action.	Unit 3-B, Job Sheet 5—Clean and inspect cylinder bores. Unit 3-B, Job Sheet 6—Install cylinder liners and set liner protrusion.
II. C. 5.—Replace/reinstall cylinder liners and seals; check and adjust liner height (protrusion).	Unit 3-B, Job Sheet 6—Install cylinder liners and set liner protrusion.
II. C. 6.—Inspect in-block camshaft bearings for wear and damage; determine needed action.	Unit 6-B, Job Sheet 2—Remove, inspect, and install cam bushings.
II. C. 7.—Inspect, measure, and replace/reinstall in-block camshaft; measure/adjust end play.	Unit 6-B, Job Sheet 1—Remove, clean, and inspect a camshaft. Unit 6-B, Job Sheet 3—Install a camshaft and set cam timing.
II. C. 8.—Clean and inspect crankshaft for surface cracks and journal damage; check condition of oil passages; check passage plugs; measure journal diameter; determine needed action.	Unit 4-B, Job Sheet 1—Remove, clean, and inspect a crankshaft.
II. C. 9.—Inspect main bearings for wear patterns and damage; replace as needed; check bearing clearances; check and adjust crankshaft end play.	Unit 4-B, Job Sheet 1—Remove, clean, and inspect a crankshaft.
II. C. 10.—Inspect, install, and time gear train; measure gear backlash; determine needed action.	Unit 6-B, Job Sheet 3—Install a camshaft and set cam timing.

NATEF Crosswalk

NATEF Tasks	MAVCC Tasks
II. DIESEL ENGINES (cont.)	
II. C. 11.—Inspect connecting rod and bearings for wear patterns; measure pistons, pins, retainers, and bushing; perform needed action.	Unit 5-B, Job Sheet 1—Remove, disassemble, and inspect a piston and connecting rod assembly.
II. C. 12.—Determine piston-to-cylinder wall clearance; check ring-to-groove clearance and end gap; install rings on pistons.	Unit 5-B, Job Sheet 2—Measure piston-to-cylinder wall clearance and ring end gap.
II. C. 13.—Assemble pistons and connecting rods; install in block; replace rod bearings and check clearances.	Unit 5-B, Job Sheet 3—Assemble and install piston and connecting rod assembly.
II. C. 14.—Check piston cooling jets (nozzles) condition, position, and clearances.	Unit 5-B, Job Sheet 3—Assemble and install piston and connecting rod assembly.
II. C. 15.—Inspect and measure crankshaft vibration damper; determine needed action.	Unit 4-B, Job Sheet 4—Inspect viscous vibration damper/harmonic balancer. Unit 4-B, Job Sheet 5—Inspect bonded vibration damper/harmonic balancer.
II. C. 16.—Inspect, install, and align flywheel housing.	Unit 4-B, Job Sheet 6—Inspect flywheel.
II. C. 17.—Inspect flywheel/flexplate (including ring gear) and mounting surfaces for cracks and wear; measure runout; determine needed action.	Unit 4-B, Job Sheet 1—Remove, clean, and inspect a crankshaft.
D. Lubrication Systems Diagnosis and Repair	
II. D. 1.—Test engine oil pressure and check operation of pressure sensor, gauge, and/or sending unit; determine needed action.	Unit 1-D, Job Sheet 4—Check oil pressure.
II. D. 2.—Check engine oil level and condition; determine needed action.	Unit 1-C, Job Sheet 1—Check fuel level, quality, and consumption.
II. D. 3.—Inspect and measure oil pump, drives, inlet pipes, and pick-up screens; determine needed action.	Unit 1-B, Job Sheet 1—Service and install oil pump and oil pump drive components. Unit 1-B, Job Sheet 2—Service and inspect lubrication system screens and pipes.
II. D. 4.—Inspect oil pressure regulator valve(s), by-pass and pressure relief valve(s), oil thermostat, and filters; determine needed action.	Unit 1-B, Job Sheet 3vService and inspect oil pressure regulator valve and bypass valves.
II. D. 5.—Inspect, clean, and test oil cooler and components; determine needed action.	Unit 1-B, Job Sheet 4—Service and inspect oil cooler and lines.
II. D. 6.—Inspect turbocharger lubrication system; determine needed action.	Unit 8-B, Job Sheet 2—Inspect and service turbo/supercharter and related components.
E. Cooling System Diagnosis and Repair	
II. E. 1.—Check engine coolant level, condition, and consumption; determine needed action.	Unit 2-B, Job Sheet 1—Flush, refill, and bleed coolant system. Unit 2-D, Job Sheet 1—Inspect engine coolant level and condition.
II. E. 2.—Test coolant temperature and check operation of temperature sensor, gauge, and/or sending unit; determine needed action.	Unit 2-B, Job Sheet 6—Check operation and accurancy of temperature indicating system.
II. E. 3.—Inspect drive belts, tensioners, and pulleys; replace and adjust as needed.	Unit 2-B, Job Sheet 2—Inspect water pump, belts, and hoses.

NATEF Tasks	MAVCC Tasks
II. DIESEL ENGINES (cont.)	
II. E. 4.—Inspect thermostat(s), by-passes, housing(s), and seals; replace as needed.	Unit 2-B, Job Sheet 4—Test operation of thermostat installed in engine. Unit 2-D, Job Sheet 5—Test operation of thermostat on the bench.
II. E. 5.—Test coolant for freeze protection and additive package concentrate; adjust as needed.	Unit 2-D, Job Sheet 1—Inspect engine coolant level and condition.
II. E. 6.—Recover, flush, and refill with recommended coolant/additive package concentration; adjust as needed.	Unit 2-B, Job Sheet 1—Flush, refill, and bleed coolant system.
II. E. 7.—Inspect coolant conditioner/filter assembly for leaks; inspect valves, lines, and fittings; replace as needed.	Unit 2-D, Job Sheet 1—Inspect engine coolant level and condition.
II. E. 8.—Inspect water pump, hoses, and idler pulley; replace as needed.	Unit 2-B, Job Sheet 2—Inspect water pump, belts, and hoses.
II. E. 9.—Inspect, clean, and pressure test radiator, pressure cap, and tank(s) and recovery systems; determine needed action.	Unit 2-B, Job Sheet 1—Flush, refill, and bleed coolant system. Unit 2-D, Job Sheet 2—Pressure test coolant system and radiator cap.
II. E. 10.—Inspect thermostatic cooling fan system and fan shroud; replace as needed.	Unit 2-B, Job Sheet 3—Check operation of fan assembly and controls.
F. Air Induction and Exhaust Systems Diagnosis and Repair	
II. F. 1.—Inspect turbocharger wastegate, and piping systems; determine needed action.	Unit 8-B, Job Sheet 1—Inspect and test air induction system.
II. F. 2.—Test operation of exhaust mounted engine warm up device; determine needed action.	Not covered.
II. F. 3.—Remove and reinstall turbocharger and wastegate.	Unit 8-B, Job Sheet 2—Inspect and service turbo/supercharter and related components.
II. F. 4.—Inspect intake manifold, gaskets, and connections; replace as needed.	Unit 8-B, Job Sheet 1—Inspect and test air induction system.
II. F. 5.—Inspect, clean, and test aftercooler (intercooler) and charge air cooler assemblies; replace as needed.	Unit 8-B, Job Sheet 3—Clean and test jacket water intercooler. Unit 8-B, Job Sheet 4—Clean and test air-to-air intercooler.
II. F. 6.—Inspect exhaust manifold, piping, mufflers, and mounting hardware; repair or replace as needed.	Unit 8-B, Job Sheet 5—Inspect and test exhaust system.
II. F. 7.—Inspect and test preheater/inlet air heater, or glow plug system and controls; perform needed action.	Unit 8-B, Job Sheet 6—Inspect starting preheater controls. Unit 8-B, Job Sheet 7—Test starting fluid system and controls.
G. Fuel System Diagnosis and Repair	
1. Fuel Supply System Diagnosis and Repair	
II. G. 1. 1.—Check fuel level and quality; determine needed action.	Unit 1-C, Job Sheet 1—Check fuel level, quality, and consumption.
II. G. 1. 2.—Inspect fuel tanks, vents, caps, mounts, valves, screens, crossover system, supply and return lines and fittings; determine needed action.	Unit 1-C, Job Sheet 2—Inspect and service basic fuel supply components.

NATEF Tasks	MAVCC Tasks
II. DIESEL ENGINES (cont.)	
II. G. 1. 3.—Inspect, clean, and test fuel transfer (lift) pump, pump drives, screens, fuel/water separators/indicators, filters, heaters, coolers, ECM cooling plates, and mounting hardware; determine needed action.	Unit 3-C, Job Sheet 5—Remove, inspect, and rebuild or replace a fuel transfer pump.
II. G. 1. 4.—Inspect and test low pressure regulator systems (check valves, pressure regulator valves, and restrictive fittings); determine needed action.	Unit 1-C, Job Sheet 2—Inspect and service basic fuel supply components.
II. G. 1. 5.—Check fuel system for air; determine needed action; prime and bleed fuel system; check primer pump.	Unit 1-C, Job Sheet 2—Inspect and service basic fuel supply components.
2. Mechanical Fuel Injection Diagnosis and Repair	
II. G. 2. 1.—Perform on-engine inspections, tests, and adjustments; check and adjust timing or replace and time a distributor (rotary) type injection pump; determine needed action.	Unit 2-C, Job Sheet 3—Inspect, test, adjust, and time a distributor-type (rotary) injection pump; determine needed repairs.
II. G. 2. 2.—Perform on-engine inspections, tests, and adjustments; check and adjust timing or replace and time an in-line type injection pump; determine needed action.	Unit 2-C, Job Sheet 4—Inspect, test, adjust, and time an in-line injection pump; determine needed repairs.
II. G. 2. 3.—Perform on-engine inspections, tests, and adjustments; replace a PT-type injection pump and injectors as needed.	Unit 2-C, Job Sheet 5—Inspect, test, and adjust a PT injection pump and time the injectors; determine needed repairs.
II.G. 2. 4.—Inspect and adjust throttle control linkage; determine needed action	Unit 2-C, Job Sheet 3—Inspect, test, adjust, and time a distributor-Type (rotary) injection pump; determine needed repairs.
II. G. 2. 5.—Inspect air/fuel ratio control systems; determine needed action.	Unit 2-C, Job Sheet 1—Isolate, remove, test, rebuild or replace, and reinstall injection nozzles.
II. G. 2. 6.—Inspect, test, and adjust engine fuel shut-down devices and controls; determine needed action.	Not covered.
II. G. 2. 7.—Inspect high pressure injection lines, hold down fittings and seals; replace as needed.	Unit 2-C, Job Sheet 5—Inspect, test, and adjust a PT injection pump and time the injectors; determine needed repairs. Unit 2-D, Job Sheet 5—Perform a daily preventive maintenance check.
3. Electronic Fuel Management System Diagnosis and Repair	
II. G. 3. 1.—Inspect and test power and ground circuits and connections; determine needed action.	Unit 3-C, Job Sheet 1—Inspect and test power and ground circuits and connections; determine needed repairs.
II. G. 3. 2.—Interface with vehicle's on-board computer; perform diagnostic procedures using recommended electronic diagnostic equipment and tools (to include PC based software and/or data scan tools); determine needed action.	Unit 3-C, Job Sheet 2—Check diagnostic trouble codes using scan tools and technical information; determine needed repairs.

NATEF Tasks	MAVCC Tasks
II. DIESEL ENGINES (cont.)	
II. G. 3. 3.—Locate and use relevant service information (to include diagnostic procedures, flow charts, and wiring diagrams).	Throughout publication.
II. G. 3. 4.—Inspect and replace electrical connector terminals, seals, and locks.	Unit 3-C, Job Sheet 3—Inspect and replace electrical connectors, terminals, seals, and locks.
II. G. 3. 5.—Inspect and test sensors, controls, actuator components and circuits; adjust or replace as needed.	Unit 3-C, Job Sheet 2—Check diagnostic trouble codes using scan tools and technical information; determine needed repairs. Unit 2-D, Job Sheet 4—Inspect and test indicator system components.
II. G. 3. 6.—Using recommended electronic diagnostic tools (to include PC base software and/or data scan tools), access and change customer parameteres.	Unit 3-C, Job Sheet 4—Access engine parameters; monitor or change as requested by customer.
II. G. 3. 7.—Inspect, test, and adjust electronic unit injectors (EUI); determine needed action.	Unit 3-C, Job Sheet 6—Remove, inspect, reinstall, and adjust electronic unit injectors; determine needed repairs.
II. G. 3. 8.—Remove and install electronic unit injectors (EUI) and related components; recalibrate ECM (if applicable).	Unit 3-C, Job Sheet 6—Remove, inspect, reinstall, and adjust electronic unit injectors; determine needed repairs.
II. G. 3. 9.—Perform cylinder power balance utilizing electronic scan tool.	Unit 3-C, Job Sheet 4—Access engine parameters; monitor or change as requested by customer.
II. G. 3. 10.—Perform engine timing sensor calibration (if applicable).	Unit 3-C, Job Sheet 4—Access engine parameters; monitor or change as requested by customer.
II. G. 3. 11.—Perform on-engine inspections and tests on hydraulic electronic unit injectors (HEUI) and system electronic controls; determine needed action.	Unit 3-C, Job Sheet 6—Remove, inspect, reinstall, and adjust electronic unit injectors; determine needed repairs.
II. G. 3. 12.—Perform on-engine inspections and tests on hydraulic electronic unit injectors (HEUI) high pressure oil control system; determine needed action.	Unit 3-C, Job Sheet 6—Remove, inspect, reinstall, and adjust electronic unit injectors; determine needed repairs.
II. G. 3. 13.—Perform on-engine inspections and tests on distributor-type injection pump electronic controls; determine needed action.	Unit 2-C, Job Sheet 3—Inspect, test, adjust, and time a distributor-type (rotary) injection pump; determine needed repairs.
II. G. 3. 14.—Perform on-engine inspections and tests on in-line type injection pump electronic controls; determine needed action.	Unit 2-C, Job Sheet 5—Inspect, test, and adjust a PT injection pump and time the injectors; determine needed repairs.

28

NATEF Crosswalk

NATEF Tasks	MAVCC Tasks
II. DIESEL ENGINES (cont.)	
H. Engine Brakes	
II. H. 1.—Inspect and adjust engine/exhaust brakes; determine needed action.	Unit 9-B, Job Sheet 1—Remove, inspect, install, and adjust a Jacobs engine brake.
II. H. 2.—Inspect, test, and adjust engine/exhaust brake control circuits, switches, and solenoids; repair or replace as needed.	Unit 9-B, Job Sheet 1—Remove, inspect, install, and adjust a Jacobs engine brake.
II. H. 3.—Inspect engine/exhaust brake housing, valves, seals, screens, lines, and fittings; repair or replace as needed.	Unit 9-B, Job Sheet 1—Remove, inspect, install, and adjust a Jacobs engine brake.

Diesel Technology: Engines

Instructional/Task Analysis

Related Information: What the Student Should Know

Application: What the Student Should Be Able to Do

Section A: Introduction to Engine Principles and Procedures

Unit 1–A: Engine Operating Principles

1. Terms and definitions
2, Basic engine systems and their functions
3. Basic diesel engine components
4. Basic internal engine components and their functions
5. Characteristics of gasoline and diesel engines
6. Four-stroke cycle
7. Two-stroke cycle
8. Characteristics of two-stroke and four-stroke diesel engines
9. Identify companion cylinders
10. Locate and record engine specifications
11. Identify valve and piston position during each stroke
12. Locate TDC for #1 piston
13. Measure bore and stroke and compute engine displacement

Unit 2–A: Disassembly Procedures and Analysis

1. Terms and definitions
2. Special engine tools and their functions
3. Precision measuring instruments and their functions
4. Safety guidelines to following during engine removal and disassembly
5. Good housekeeping practices and procedures
6. Accessory components and lines that must be pulled (disconnected) before the engine is removed
7. Methods for cleaning engine components
8. Engine components that require measurement and analysis
9. Types of materials used on engine components and their applications
10. Types of analyses
11. Eight steps of failure analysis
12. Normal and abnormal wear
13. Common types of mechanical wear and their characteristics
14. Root causes of system failures
15. Determine required tools for various tasks
16. Evaluate worn engine components
17. Determine possible causes of engine component failures
18. Steam clean an engine
19. Remove engine accessories and external lines
20. Remove engine and mount on an engine stand
21. Engine disassembly: Remove cylinder head
22. Engine disassembly: Remove gear train and camshaft
23. Engine disassembly: Remove pistons and connecting rods
24. Engine disassembly: Remove cylinder liners
25. Engine disassembly: Remove crankshaft

Instructional/Task Analysis

Related Information: What the Student Should Know

Application: What the Student Should Be Able to Do

Section B: Engine Systems And Components

Unit 1–B: Lubrication Systems

1. Terms and definitions
2. Lubrication system components
3. Functions of lubrication system components
4. Basic types of oil filters and their operations
5. Basic oil pump designs and their operation
6. Basic oil cooler designs
7. Basic oil cooler operation
8. Sources of oil contamination
9. Lubrication system monitor operation
10. API use codes
11. Factors to consider when choosing an engine oil
12. Service and install oil pump and oil pump drive components
13. Service and inspect lubrication system screens and pipes
14. Service and inspect oil pressure regulator valve and bypass valve
15. Service and inspect oil cooler and lines

Unit 2–B: Cooling Systems

1. Terms and definitions
2. Common types of cooling systems
3. Typical cooling system components for air-cooled engines
4. Typical cooling system components for liquid-cooled engines
5. Cooling system operation
6. Effects of incorrect temperature regulation
7. Common types of radiators
8. Types of drives for water pumps
9. Parts of a water pump
10. Types of drive belts
11. Functions of coolant filters, conditioners, and additives
12. Types of antifreeze
13. Characteristics of a suitable antifreeze
14. Purposes of a radiator cap
15. Typical radiator cap operation
16. Flush, refill, and bleed coolant system
17. Inspect water pump, belts, and hoses
18. Check operation of fan assembly and controls
19. Test operation of thermostat installed in engine
20. Test operation of thermostat on the bench
21. Check operation and accuracy of temperature indicating system

Related Information: What the Student Should Know

Application: What the Student Should Be Able to Do

Unit 3–B: Cylinder Blocks and Liners

1. Terms and definitions
2. Types of cylinder block cooling methods
3. Types of cylinder block liners (sleeves)
4. Characteristics of cylinder liners (sleeves)
5. Cause of abnormal sleeve wear
6. Pressure test a cylinder block
7. Disassemble and clean a cylinder block
8. Inspect a cylinder block
9. Install new camshaft bushings
10. Clean and inspect cylinder bores
11. Install cylinder liners and set liner protrusion

Unit 4–B: Crankshafts and Bearings

1. Terms and definitions
2. Parts of a crankshaft
3. Crankshaft throw arrangements
4. Crankshaft throw characteristics
5. Crankshaft balancing methods
6. Crankshaft lubrication
7. Characteristics of a good bearing
8. Bearing materials and their characteristics
9. Parts of main and connecting rod bearings
10. Special design features of main bearings
11. Types of thrust bearings
12. Symptoms of bearing failure
13. Types of vibration dampers
14. Functions of a flywheel
15. Remove, clean, and inspect a crankshaft
16. Install main bearings and crankshaft
17. Perform an in-frame bearing roll-in
18. Inspect viscous vibration damper/harmonic balancer
19. Inspect bonded vibration damper/harmonic balancer
20. Inspect flywheel

Unit 5–B: Pistons and Connecting Rods

1. Terms and definitions
2. Primary components of a piston and connecting rod assembly
3. Functions of piston and connecting rod components
4. Parts of a piston
5. Functions of piston parts
6. Common piston designs
7. Types of piston crown designs

Instructional/Task Analysis

Related Information: What the Student Should Know

Application: What the Student Should Be Able to Do

Unit 5–B: Pistons and Connecting Rods (continued)

Related Information: What the Student Should Know

8. Types of piston rings and their functions
9. Common types of piston ring end gaps
10. Piston ring designs
11. Characteristics of piston ring designs
12. Parts of a connecting rod
13. Connecting rod parts and their descriptions
14. Common causes of abnormal piston wear
15. Possible causes of high oil consumption and blow-by

Application: What the Student Should Be Able to Do

16. Remove, disassemble, and inspect a piston and connecting rod assembly
17. Measure piston-to-cylinder wall clearance and ring end gap
18. Assemble and install piston and connecting rod assembly

Unit 6–B: Camshafts, Trains, and Timing

Related Information: What the Student Should Know

1. Terms and definitions
2. Primary parts of a camshaft
3. Types of camshafts
4. Operation of a camshaft
5. Parts of a cam lobe
6. Parts of a valve train
7. Valve actuation
8. Valve timing
9. Types of camshaft bushings
10. Types of cam followers and lifters
11. Methods of driving the camshaft
12. Components in a typical gear train
13. Gear timing

Application: What the Student Should Be Able to Do

14. Remove, clean, and inspect a camshaft
15. Remove, inspect, and install cam bushings
16. Install a camshaft and set cam timing

Related Information: What the Student Should Know

Application: What the Student Should Be Able to Do

Unit 7–B: Cylinder Head Assemblies

1. Terms and definitions
2. Functions of a cylinder head
3. Basic differences between basic cylinder head designs
4. Parts of a typical valve
5. Functions of valve parts
6. Basic valve assembly components
7. Functions of valve assembly components
8. Operation of a valve rotator
9. Common cylinder head problems
10. Common valve/seat problems
11. Locate and label intake and exhaust valves
12. Clean and inspect a cylinder head
13. Recondition a cylinder head
14. Install a cylinder head assembly and adjust valves

Unit 8–B: Air Induction and Exhaust Systems

1. Terms and definitions
2. Basic air induction components
3. Functions of air induction components
4. Types of air induction systems
5. Main parts of a turbocharger
6. Starting aid devices
7. Basic exhaust system components
8. Functions of exhaust system components
9. Operation of an induction and exhaust system
10. Diesel engine scavenging
11. Exhaust systems
12. Parts of a typical catalytic converter
13. Operation of a catalytic converter
14. Inspect and test air induction system
15. Inspect and service turbo/supercharger and related components
16. Clean and test jacket water intercooler
17. Clean and test air-to-air intercooler
18. Inspect and test exhaust system
19. Inspect starting preheater controls
20. Test starting fluid system and controls

Related Information: What the Student Should Know

Application: What the Student Should Be Able to Do

Unit 9–B: Engine Brakes and Retarders

1. Terms and definitions
2. Common types of engine brakes and retarders
3. Advantages of engine brake and retarder systems
4. Engine compression brake components
5. Functions of engine compression brake components
6. Engine operation with the engine compression brake energized
7. Exhaust brake components
8. Functions of exhaust brake components
9. Engine operation with the exhaust brake energized (throttle-off operation)
10. Hydraulic engine retarder components (BrakeSaver®)
11. Functions of hydraulic engine retarder components
12. Engine operation with the hydraulic engine retarder energized
13. Electric driveline retarder components
14. Functions of electric driveline retarder components
15. Engine operation with an electric driveline retarder energized
16. Remove, inspect, install, and adjust a Jacobs Engine Brake
17. Check operation of a BrakeSaver®
18. Check operation of an exhaust brake
19. Remove, clean, and install an exhaust brake
20. Check operation of a driveline retarder

Section C: Fuel Systems

Unit 1–C: Basic Fuel Systems and Components

1. Terms and definitions
2. Major functions of fuel systems
3. Major parts of a fuel system
4. Functions of fuel system parts
5. Parts of fuel tanks
6. Types of fuel transfer pumps
7. Types of primer pumps
8. Types of fuel injection systems

Related Information: What the Student Should Know

Application: What the Student Should Be Able to Do

Unit 1–C: Basic Fuel Systems and Components (continued)

9. Methods of injecting fuel
10. Types of controls on fuel systems
11. Types of fuel lines and their functions
12. Types of fuel filters
13. Types of governors
14. Classes of governors
15. Operation of the mechanical governor
16. Common maintenance problems on fuel systems
17. Factors that affect fuel consumption
18. Trace fuel flow through basic fuel systems
19. Check fuel level, quality, and consumption
20. Inspect and service basic fuel supply components

Unit 2–C: Mechanical Fuel Injection Diagnosis and Repair

1. Terms and definitions
2. Parts of injection nozzles
3. Types of nozzle valves
4. Operation of an injection nozzle
5. Parts of mechanical unit injectors
6. Fuel flow through the unit injector
7. Optional features on fuel injection pumps
8. Main parts of a distributor-type injection pump
9. Functions of main parts of a distributor-type injection pump
10. Operation of distributor-type injection pumps
11. Fuel flow through distributor-type injection pumps
12. Main parts of an in-line injection pump
13. Functions of main parts of an in-line injection pump
14. Operation of an in-line injection pump
15. Parts and design features of a pumping element
16. Operation of control rack and sleeve
17. Plunger and rack positions
18. Types of PT injection pumps
19. Main parts of a PT injection pump

Related Information: What the Student Should Know

Application: What the Student Should Be Able to Do

Unit 2–C: Mechanical Fuel Injection Diagnosis and Repair (continued)

20. Functions of the main parts of a PT injection pump
21. Operation of a PT injection pump
22. Types of PT injectors
23. Operation of PT injectors

24. Isolate, remove, test, rebuild or replace, and reinstall injection nozzles
25. Isolate, remove, test, and reinstall or replace mechanical unit injectors
26. Inspect, test, adjust, and time a distributor-type (rotary) injection pump; determine needed repairs
27. Inspect, test, adjust, and time an in-line injection pump; determine needed repairs
28. Inspect, test, and adjust a PT injection pump and time the injectors; determine needed repairs

Unit 3–C: Electronic Fuel Injection Diagnosis and Repair

1. Terms and definitions
2. Parts of a typical electronic fuel system
3. Fuel flow through an electronic fuel system
4. Parts of an electronic unit injector
5. Advantages of electronic fuel injection over mechanical fuel injection
6. Common types of electronic fuel injection systems
7. Basic categories of electronic components
8. Common electronic sensors
9. Common electronic acronyms or abbreviations and their meanings
10. Specialty tools and equipment used for electronic diagnosis
11. Basic types of diagnostic codes
12. Electronic identification message codes

13. Inspect and test power and ground circuits and connections; determine needed repairs
14. Check diagnostic trouble codes using electronic diagnostic equipment and technical information; determine needed repairs
15. Inspect and replace electrical connectors, terminals, seals, and locks
16. Access engine parameters; monitor or change as requested by customer
17. Remove, inspect, and rebuild or replace a fuel transfer pump
18. Remove, inspect, reinstall, and adjust electronic unit injectors; determine needed repairs

Related Information: What the Student Should Know

Application: What the Student Should Be Able to Do

Unit 4–C: Emissions

1. Terms and definitions
2. Diesel fuel combustion reaction
3. Exhaust emissions and their characteristics
4. Types of smoke emissions
5. Environmental issues affected by emissions
6. Federal Clean Air Act
7. Tests for emissions
8. Efforts to improve emissions
9. Alternative/clean fuels
10. Methods for reducing noise levels
11. Check vehicle for presence and operation of emission control devices
12. Check vehicle for fuel type and appropriate application
13. Test vehicle for excessive exhaust smoke
14. Check vehicle for noise abatement devices

Section D: Engine Diagnosis and Maintenance

Unit 1–D: General Engine Diagnosis

1. Terms and definitions
2. Steps used in evaluating engine performance
3. Benefits of the operator questionnaire
4. Major checkpoints in a visual inspection
5. Major performance checkpoints
6. Performance tests made with the engine on a dynamometer
7. Functions of engine computer fault detection
8. Engine computer fault code storage
9. Engine computer fault code retrieval
10. SAE code identifiers
11. Conduct an operator survey for engine diagnosis
12. Interpret SAE code identifiers
13. Check air intake system for restrictions
14. Check exhaust back pressure
15. Check crankcase pressure
16. Check oil pressure
17. Load test an engine on a dynamometer
18. Locate a misfiring cylinder
19. Locate an active fault code

Instructional/Task Analysis

Unit 2–D: Preventive Maintenance and Tune-Up

Related Information: What the Student Should Know

1. Terms and definitions
2. Purposes of preventive maintenance and tune-up
3. Locating preventive maintenance charts and information
4. Ways of designating preventive maintenance intervals
5. Conditions that require severe service maintenance schedules
6. Engine areas requiring preventive maintenance
7. Preventive maintenance tasks for diesel fuel systems
8. Diesel engine tune-up sequence

Application: What the Student Should Be Able to Do

9. Determine maintenance needed for given situations
10. Interpret maintenance troubleshooting charts
11. Inspect engine coolant level and condition
12. Pressure test coolant system and radiator cap
13. Take oil sample, and change oil and filter(s)
14. Inspect and test indicator system components
15. Perform a daily preventive maintenance check
16. Perform a mileage preventive maintenance check
17. Perform an engine tune-up

Basic Skills Icons and Classifications

To assist teachers and students in identifying and documenting where academic and workplace skills are being taught, MAVCC has adopted a system that uses icons and a list of specific tasks to identify the skill or skills that are used in each focus assignment, assignment sheet, and job sheet.

A matrix for each of the ten broad skill areas has been included in this edition and reflects key elements from *What Work Requires of Schools: A SCANS Report for America 2000*, a 1991 study by the U.S. Department of Labor; *Workplace Basics: The Skills Employers Want*, a three-year study conducted jointly by the American Society for Training and Development (ASTD) and the United States Department of Labor (DOL); and other national and state sources.

Each of the ten broad skill areas—reading, writing, mathematics, science, oral communication, interpersonal or relating, critical thinking, employability, social studies, and technology—is represented by the icon presented below.

Reading Skills

- Reading Comprehension
- Research/Reference
- Functional Reading

Writing Skills

- Language
- Composition
- Research
- Functional Writing

Math Skills

- Operation and Calculation
- Math Application
- Data Analysis and Display
- Functional Math

Basic Skills Icons and Classifications

Science Skills

- General Science
- Life Science
- Physical Science
- Earth Science

Oral Communication Skills

- Oral Presentation
- Listening
- Interactive Communication

Interpersonal or Relating Skills

- General Relating
- Teamwork/Cooperation
- Leadership/Influence

Critical Thinking Skills

- Cognitive Activities

Employability Skills

- Job Search/Selections
- Job Acquisition/Development
- Resource Management
- Job Safety

Social Studies Skills

- Information Analysis
- Social Studies Application
- Functional Social Studies

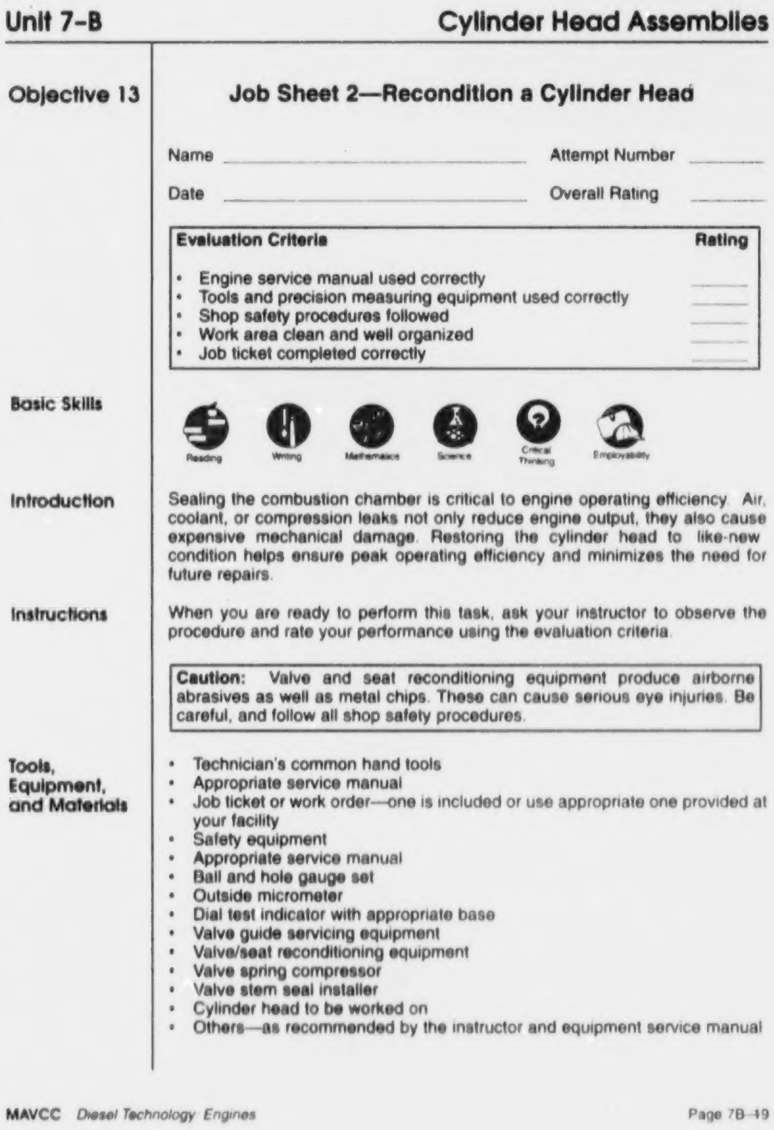
Technology Skills

- Selection
- Application
- Maintenance/Troubleshooting

Basic Skills Icons and Classifications

When an activity involving one of these basic skills is identified, the corresponding icon is placed in the left-hand margin of the focus assignment, assignment sheet, and job sheet. Skills training is further defined by classifying specific skills that are required. (See skills list that may be found on each basic skills matrix.)

Example:



Unit 7-B **Cylinder Head Assemblies**

Objective 13

Job Sheet 2—Recondition a Cylinder Head

Name ____________________ Attempt Number ______

Date ____________________ Overall Rating ______

Evaluation Criteria	**Rating**
• Engine service manual used correctly	______
• Tools and precision measuring equipment used correctly	______
• Shop safety procedures followed	______
• Work area clean and well organized	______
• Job ticket completed correctly	______

Basic Skills

Reading Writing Mathematics Science Critical Thinking Employability

Introduction

Sealing the combustion chamber is critical to engine operating efficiency. Air, coolant, or compression leaks not only reduce engine output, they also cause expensive mechanical damage. Restoring the cylinder head to like-new condition helps ensure peak operating efficiency and minimizes the need for future repairs.

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Caution: Valve and seat reconditioning equipment produce airborne abrasives as well as metal chips. These can cause serious eye injuries. Be careful, and follow all shop safety procedures.

Tools, Equipment, and Materials

- Technician's common hand tools
- Appropriate service manual
- Job ticket or work order—one is included or use appropriate one provided at your facility
- Safety equipment
- Appropriate service manual
- Ball and hole gauge set
- Outside micrometer
- Dial test indicator with appropriate base
- Valve guide servicing equipment
- Valve/seat reconditioning equipment
- Valve spring compressor
- Valve stem seal installer
- Cylinder head to be worked on
- Others—as recommended by the instructor and equipment service manual

MAVCC *Diesel Technology Engines* Page 7B-19

Reading Skills

Reading Comprehension

- Gain factual information
- Distinguish fact, opinion, and inference
- Recognize stereotyping and bias
- Recognize propaganda
- Analyze cause and effect
- Draw conclusions
- Make generalizations
- React to written material
- Apply word analysis techniques
- Analyze and apply what has been read to specific task
- Comprehend written information for main ideas
- Determine what information is needed

Research/ Reference

- Select useful resources
- Locate resources
- Find materials in library
- Use standard references
- Use in-book reference tools
- Use audiovisual media
- Use computer database
- Use magazines and newspapers

Functional Reading

- Interpret forms and records
- Follow written instructions
- Interpret graphics and symbols
- Interpret abbreviations/acronyms
- Read aloud
- Apply/understand technical words that pertain to subject

Writing Skills

Language	• Use standard grammar, spelling, and capitalization • State ideas clearly
Composition	• Use complete sentences • Develop preliminary outline • Use topic sentences • Use introductory/closing paragraphs • Compose reports • Compose essays • Proofread and edit • Construct graphics and symbols
Research	• Take notes • Use note cards • Create bibliography • Use footnotes • Outline material
Functional Writing	• Complete forms and records • Write instructions • Write letters • Write job applications • Write resumes • Use word processing • Use computer graphics • Use content area vocabulary

Math Skills

Operation and Calculation

- Round off numbers
- Estimate answers
- Use scientific notations
- Use exponential notations
- Calculate with whole numbers
- Calculate with fractions
- Calculate with decimals
- Convert whole numbers to fractions
- Convert whole numbers to decimals
- Solve numerical expressions
- Solve formulae and equations
- Obtain squares and square roots
- Convert units of measure
- Perform metric calculations

Math Application

- Solve word problems
- Select/apply mathematical formula
- Select/apply mathematical procedure
- Use English and metric measures
- Solve time/rate/distance problems
- Solve ratio/proportion problems
- Solve percent problems
- Apply techniques of scaling
- Apply algebra principles
- Apply geometry principles
- Apply trigonometry principles

Data Analysis and Display

- Interpret charts and tables
- Interpret graphs
- Collect/record data
- Apply sampling techniques
- Apply principles of probability
- Construct charts and tables
- Construct graphs
- Calculate statistics
- Interpret statistics
- Interpret plans/blueprints
- Draw facility to scale

Math Skills (Continued)

Functional Math

- Make measurements
- Perform banking transactions
- Make change
- Solve practical problems
- Calculate gross earnings
- Solve income/expense problems
- Prepare a budget
- Calculate interest
- Solve interest problems
- Calculate sales tax
- Determine income tax
- Use calculator for computation
- Use computer for computation
- Use computer spreadsheets
- Calculate measurements taken from measuring devices

Science Skills

General Science

- Apply computing skills
- Apply scientific method of inquiry
- Conduct experiments
- Investigate science ethics
- Investigate science history
- Investigate/apply economics in technology
- Use scientific instruments
- Investigate/apply technology
- Collect specimens

Life Science

- Identify/classify living organisms
- Investigate biological history of the earth
- Investigate food chains, webs, pyramids
- Investigate/apply principles of human development
- Investigate/apply principles of genetics/heredity
- Investigate/apply principles of anatomy/physiology
- Investigate health issues
- Observe health code/sanitation requirements

Physical Science

- Analyze/classify matter
- Investigate forms/changes of matter
- Investigate forms/changes of energy
- Investigate/apply chemical properties
- Investigate/apply physical laws

Earth Science

- Investigate physical characteristics of the earth
- Investigate geological history of the earth
- Investigate physical forces acting on the earth
- Solve problems of longitude, latitude, and time zones
- Investigate conservation of physical resources
- Investigate conservation of living resources
- Investigate issues of environmental impact
- Apply science principles to environmental issues

Oral Communication Skills

Oral Presentation

- Make informative presentations
- Make persuasive presentations
- Present personal opinion/viewpoint
- Use good speaking techniques
- Select/use words effectively
- Use effective body language
- Present appropriate appearance
- Integrate audio and/or visual materials into oral presentations
- Adapt presentation to specific audience

Listening

- Apply active listening skills
- Distinguish fact, opinion, and inference
- Draw conclusions/make generalizations
- Analyze/identify point of view

Interactive Communication

- Give/follow oral directions
- Apply questioning techniques
- Conduct/receive interviews
- Analyze/apply nonverbal communication
- Work effectively in a group
- Communicate with clients/customers/patients
- Communicate with coworkers
- Communicate with supervisors
- Communicate with professional colleagues/associates
- Apply telephone etiquette

Interpersonal or Relating Skills

General Relating

- Investigate/apply communication process models
- Analyze/apply nonverbal communication
- Investigate/apply cross-cultural communication
- Interact with coworkers
- Interact with supervisors
- Interact with clients/customers/patients
- Interact with professional colleagues/associates
- Interact with family/friends
- Participate in group activities
- Participate in industrial relations/functions
- Identify personal values/attitudes
- Apply information to life experiences

Teamwork/ Cooperation

- Identify values/attitudes
- Identify needs/drives
- Select/apply appropriate behavior
- Investigate/identify personal styles
- investigate/identify group/corporate climate
- Give/receive feedback
- Identify hidden purposes
- Investigate/apply group dynamics
- Control undesirable/inappropriate behavior
- Resolve conflicts
- Clarify goals/objectives
- Devise "win/win" situations
- Build consensus
- Generate ideas
- Present point of view

Leadership/ Influence

- Analyze/apply leadership styles
- Analyze/apply management styles
- Obtain confidence of others
- Develop esteem in self/others
- Persuade others
- Analyze/apply motivation techniques
- Provide positive coaching

Basic Skills Icons and Classifications

Critical Thinking Skills

Cognitive Activities

- Collect/record information
- Identify critical elements/issues
- Define a problem
- Identify underlying causes
- Apply a problem-solving model
- Analyze/synthesize information
- Identify/analyze underlying assumptions
- Draw conclusions
- Predict results/outcomes
- Identify/evaluate consequences
- Identify/develop alternatives
- Evaluate alternatives
- Select an alternative
- Devise a solution
- Create a finished product
- Apply intuitive thinking techniques
- Transfer knowledge/training to new situations
- Apply new technology
- Develop an action plan
- Evaluate results/outcomes
- See relationship between two or more ideas, objects, or situations

Employability Skills

Job Search/ Selections

- Analyze personal occupational aptitudes/preferences
- Investigate employment prospects of a career field/occupation
- Investigate training requirements for a career field/occupation
- Investigate benefits of a career field/occupation
- Compare/evaluate career options
- Analyze impact of work on individual and family life

Job Acquisition/ Development

- Develop personal career path
- Locate appropriate jobs
- Analyze duties/requirements/benefits of specific job
- Master specific job task/procedure
- Complete job-related applications
- Write a letter of application
- Write personal resume
- Interview for a job
- Apply business etiquette
- Practice good work habits/attitudes
- Practice good personal presentation
- Develop self confidence/esteem
- Develop effective leadership
- Deal effectively with supervisors
- Deal effectively with coworkers
- Deal effectively with professional colleagues/associates
- Deal effectively with customers/clients/patients
- Follow established rules, regulations, and policies
- Promote the goals and values of the organization
- Exert a high level of effort and perseverance towards goal attainment
- Set high standards for self in completion of a task

Resource Management

- Complete task in timely manner
- Determine cost, time, and resources to complete a task
- Perform routine tasks related to equipment operation and/or maintenance

Job Safety

- Demonstrate safe use of tools, equipment, and supplies
- Observe safety rules
- Wear safety equipment
- Follow safety procedures
- Demonstrate proper use of safety device

Basic Skills Icons and Classifications

Social Studies Skills

Information Analysis

- Collect/record data
- Interpret graphical information
- Construct graphical information
- Interpret maps/globes
- Interpret statistical information
- Analyze/interpret demographic information
- Distinguish trends and predicts impact of actions on systems operations

Social Studies Application

- Investigate/apply U.S. history
- Investigate/apply world history
- Investigate/apply U.S. geography
- Investigate/apply world geography
- Investigate/apply principles of government/politics
- Investigate/apply principles of economics
- Investigate/apply principles of ethics
- Investigate/apply principles of sociology
- Investigate/apply cross-cultural studies

Functional Social Studies

- Practice responsible personal economics
- Prepare a personal budget
- Use credit responsibly
- Practice good work ethics
- Participate in industrial relations
- Interact with people of different races/cultures
- Investigate/participate in government
- Investigate/apply American legal practices
- Select/use sources of information on current events
- Analyze current events
- Analyze consumer issues
- Analyze social issues
- Analyze conservation/ecology issues
- Analyze social impact of science/technology
- Analyze economic impact of science/technology
- Understand how social, organizational, and technological systems work and operate effectively

Technology Skills

Selection	• Choose procedures, tools, or equipment including computers and related technologies that will produce the desired results
Application	• Demonstrate the proper procedures for setting up and operating equipment, including computers and their programming systems
Maintenance/ Troubleshooting	• Perform maintenance on equipment, including computers and other technologies • Identify and correct problems with equipment • Report damaged or broken equipment to appropriate individual

Basic Skills Matrix

Section A — Introduction to Engine Principles and Procedures

Unit 1-A: Engine Operating Principles

Academic and Workplace Skills

Obj. #	Task	Icon	Skill	Sub Skill	Description
9	Identify companion cylinders (AS-1)	📚	Reading	Functional reading	Follow written instructions
		💡	Critical thinking	Cognitive activities	Draw conclusions
10	Locate and record engine specifications (AS-2)	📚	Reading	Research/ reference	Use standard references
				Functional reading	Follow written instructions
		✏	Writing	Functional writing	Complete forms and records
11	Identify valve and piston position during each stroke (AS-3)	📚	Reading	Functional reading	Follow written instructions
		💡	Critical thinking	Cognitive activities	Collect/record information Identify critical elements/issues Analyze/synthesize information Draw conclusions Predict results/outcomes
12	Locate TDC for #1 piston (JS-1)	📚	Reading	Functional reading	Follow written instructions Use content area vocabulary
		✏	Writing	Functional writing	Complete forms and records
		💡	Critical thinking	Cognitive activities	Collect/record information Identify critical elements/issues Draw conclusions
		⛑	Employability	Job acquisition/ development	Master specific job task/procedure Practice good work habits/attitudes Develop self confidence/esteem

Basic Skills Matrix

Unit 1-A: Engine Operating Principles (cont.)

Academic and Workplace Skills					
'Obj. #	Task	Icon	Skill	Sub Skill	Description
13	Measure bore and stroke and compute engine displacement (JS-2)		Reading	Functional reading	Follow written instructions Use content area vocabulary
			Writing	Functional writing	Complete forms and records
			Math	Operation and calculation	Use exponential notations Calculate with decimals
				Math application	Select/apply mathematical procedure Use English and metric measures
			Critical thinking	Cognitive activities	Collect/record information Identify critical elements/issues Draw conclusions
			Employability	Job acquisition/ development	Master specific job task/procedure Practice good work habits/attitudes Develop self confidence/esteem

Unit 2–A: Disassembly Procedures and Analysis

Academic and Workplace Skills					
Obj. #	**Task**	**Icon**	**Skill**	**Sub Skill**	**Description**
15	Determine required tools for various tasks (AS-1)	📖	Reading	Research/ reference	Use standard references
				Functional reading	Follow written instructions Use content area vocabulary
		✎	Writing	Functional writing	Complete forms and records
		?	Critical thinking	Cognitive activities	Collect/record information Draw conclusions
16	Evaluate worn engine components (AS-2)	📖	Reading	Functional reading	Follow written instructions Use content area vocabulary
		✎	Writing	Functional writing	Complete forms and records
		?	Critical thinking	Cognitive activities	Collect/record information Identify critical elements/issues Identify underlying causes Analyze/synthesize information Draw conclusions
17	Determine possible causes of engine component failures (AS-3)	📖	Reading	Research/ reference	Use standard references
				Functional reading	Follow written instructions Use content area vocabulary
		✎	Writing	Functional writing	Complete forms and records
		?	Critical thinking	Cognitive activities	Collect/record information Identify critical elements/issues Define a problem Identify underlying causes Apply a problem-solving model Analyze/synthesize information Identify/analyze underlying assumptions Draw conclusions

Basic Skills Matrix

Unit 2–A: Disassembly Procedures and Analysis (cont.)

Academic and Workplace Skills					
Obj. #	**Task**	**Icon**	**Skill**	**Sub Skill**	**Description**
18	Steam clean an engine (JS-1)	●	Reading	Functional reading	Follow written instructions Use content area vocabulary
		●	Writing	Functional writing	Complete forms and records
		?	Critical thinking	Cognitive activities	Collect/record information Identify critical elements/issues Draw conclusions
		●	Employability	Job acquisition/ development	Master specific job task/procedure Practice good work habits/attitudes Develop self confidence/esteem
19	Remove engine accessories and external lines (JS-2)	●	Reading	Functional reading	Follow written instructions Use content area vocabulary
		●	Writing	Functional writing	Complete forms and records
		?	Critical thinking	Cognitive activities	Collect/record information Identify critical elements/issues Draw conclusions
		●	Employability	Job acquisition/ development	Master specific job task/procedure Practice good work habits/attitudes Develop self confidence/esteem
20	Remove engine and mount on an engine stand (JS 3)	●	Reading	Functional reading	Follow written instructions Use content area vocabulary
		●	Writing	Functional writing	Complete forms and records
		?	Critical thinking	Cognitive activities	Collect/record information Identify critical elements/issues Draw conclusions
		●	Employability	Job acquisition/ development	Master specific job task/procedure Practice good work habits/attitudes Develop self confidence/esteem

Unit 2–A: Disassembly Procedures and Analysis (cont.)

Academic and Workplace Skills

Obj. #	Task	Icon	Skill	Sub Skill	Description
21	Engine disassembly: remove cylinder head (JS-4)	📚	Reading	Functional reading	Follow written instructions Use content area vocabulary
		✎	Writing	Functional writing	Complete forms and records
		💡	Critical thinking	Cognitive activities	Collect/record information Identify critical elements/issues Draw conclusions
		⛑	Employability	Job acquisition/ development	Master specific job task/procedure Practice good work habits/attitudes Develop self confidence/esteem
22	Engine disassembly: remove gear train and camshaft (JS-5)	📚	Reading	Functional reading	Follow written instructions Use content area vocabulary
		✎	Writing	Functional writing	Complete forms and records
		💡	Critical thinking	Cognitive activities	Collect/record information Identify critical elements/issues Draw conclusions
		⛑	Employability	Job acquisition/ development	Master specific job task/procedure Practice good work habits/attitudes Develop self confidence/esteem
23	Engine disassembly: remove pistons and connecting rods (JS-6)	📚	Reading	Functional reading	Follow written instructions Use content area vocabulary
		✎	Writing	Functional writing	Complete forms and records
		💡	Critical thinking	Cognitive activities	Collect/record information Identify critical elements/issues Draw conclusions
		⛑	Employability	Job acquisition/ development	Master specific job task/procedure Practice good work habits/attitudes Develop self confidence/esteem

Basic Skills Matrix

Unit 2-A: Disassembly Procedures and Analysis (cont.)

Academic and Workplace Skills

Obj. #	Task	Icon	Skill	Sub Skill	Description
24	Engine disassembly: remove cylinder liners (JS-7)	📚	Reading	Functional reading	Follow written instructions Use content area vocabulary
		✎	Writing	Functional writing	Complete forms and records
		💡	Critical thinking	Cognitive activities	Collect/record information Identify critical elements/issues Draw conclusions
		⛑	Employability	Job acquisition/ development	Master specific job task/procedure Practice good work habits/attitudes Develop self confidence/esteem
25	Engine disassembly: remove crankshaft (JS-8)	📚	Reading	Functional reading	Follow written instructions Use content area vocabulary
		✎	Writing	Functional writing	Complete forms and records
		💡	Critical thinking	Cognitive activities	Collect/record information Identify critical elements/issues Draw conclusions
		⛑	Employability	Job acquisition/ development	Master specific job task/procedure Practice good work habits/attitudes Develop self confidence/esteem

Section B — Engine Systems and Components

Unit 1-B: Lubrication Systems

Academic and Workplace Skills

Obj. #	Task	Icon	Skill	Sub Skill	Description
12	Service and install oil pump and oil pump drive components (JS-1)	●	Reading	Functional reading	Follow written instructions Use content area vocabulary
		●	Writing	Functional writing	Complete forms and records
		●	Math	Functional math	Make measurements
		●	Critical thinking	Cognitive activities	Collect/record information Identify critical elements/issues Draw conclusions
		●	Employability	Job acquisition/ development	Master specific job task/procedure Practice good work habits/attitudes Develop self confidence/esteem
13	Service and inspect lubrication system screens and pipes (JS-2)	●	Reading	Functional reading	Follow written instructions Use content area vocabulary
		●	Writing	Functional writing	Complete forms and records
		●	Critical thinking	Cognitive activities	Collect/record information Identify critical elements/issues Draw conclusions
		●	Employability	Job acquisition/ development	Master specific job task/procedure Practice good work habits/attitudes Develop self confidence/esteem
14	Service and inspect oil pressure regulator valve and bypass valve (JS-3)	●	Reading	Functional reading	Follow written instructions Use content area vocabulary
		●	Writing	Functional writing	Complete forms and records
		●	Critical thinking	Cognitive activities	Collect/record information Identify critical elements/issues Draw conclusions
		●	Employability	Job acquisition/ development	Master specific job task/procedure Practice good work habits/attitudes Develop self confidence/esteem

Basic Skills Matrix

Unit 1-B: Lubrication Systems (cont.)

Academic and Workplace Skills					
Obj. #	**Task**	**Icon**	**Skill**	**Sub Skill**	**Description**
15	Service and inspect oil cooler and lines (JS-4)	📚	Reading	Functional reading	Follow written instructions Use content area vocabulary
		✎	Writing	Functional writing	Complete forms and records
		💡	Critical thinking	Cognitive activities	Collect/record information Identify critical elements/issues Draw conclusions
		⛑	Employability	Job acquisition/ development	Master specific job task/procedure Practice good work habits/attitudes Develop self confidence/esteem

Unit 2-B: Cooling Systems

Academic and Workplace Skills					
Obj. #	**Objective**	**Icon**	**Skill**	**Sub Skill**	**Description**
16	Flush, refill, and bleed coolant system (JS-1)	📚	Reading	Functional reading	Follow written instructions Use content area vocabulary
		✎	Writing	Functional writing	Complete forms and records
		?	Critical thinking	Cognitive activities	Collect/record information Identify critical elements/issues Draw conclusions
		⛑	Employability	Job acquisition/ development	Master specific job task/procedure Practice good work habits/attitudes Develop self confidence/esteem
17	Inspect water pump, belts, and hoses (JS-2)	📚	Reading	Functional reading	Follow written instructions Use content area vocabulary
		✎	Writing	Functional writing	Complete forms and records
		?	Critical thinking	Cognitive activities	Collect/record information Identify critical elements/issues Draw conclusions
		⛑	Employability	Job acquisition/ development	Master specific job task/procedure Practice good work habits/attitudes Develop self confidence/esteem
18	Check operation of fan assembly and controls (JS-3)	📚	Reading	Functional reading	Follow written instructions Use content area vocabulary
		✎	Writing	Functional writing	Complete forms and records
		?	Critical thinking	Cognitive activities	Collect/record information Identify critical elements/issues Draw conclusions
		⛑	Employability	Job acquisition/ development	Master specific job task/procedure Practice good work habits/attitudes Develop self confidence/esteem

Basic Skills Matrix

Unit 2-B: Cooling Systems (cont.)

Academic and Workplace Skills					
Obj. #	**Task**	**Icon**	**Skill**	**Sub Skill**	**Description**
19	Test operation of thermostat installed in engine (JS-4)	📚	Reading	Functional reading	Follow written instructions Use content area vocabulary
		✎	Writing	Functional writing	Complete forms and records
		?	Critical thinking	Cognitive activities	Collect/record information Identify critical elements/issues Draw conclusions
		⛑	Employability	Job acquisition/ development	Master specific job task/procedure Practice good work habits/attitudes Develop self confidence/esteem
20	Test operation of thermostat on the bench (JS-5)	📚	Reading	Functional reading	Follow written instructions Use content area vocabulary
		✎	Writing	Functional writing	Complete forms and records
		?	Critical thinking	Cognitive activities	Collect/record information Identify critical elements/issues Draw conclusions
		⛑	Employability	Job acquisition/ development	Master specific job task/procedure Practice good work habits/attitudes Develop self confidence/esteem
21	Check operation and accuracy of temperature indicating system (JS-6)	📚	Reading	Functional reading	Follow written instructions Use content area vocabulary
		✎	Writing	Functional writing	Complete forms and records
		?	Critical thinking	Cognitive activities	Collect/record information Identify critical elements/issues Draw conclusions
		⛑	Employability	Job acquisition/ development	Master specific job task/procedure Practice good work habits/attitudes Develop self confidence/esteem

Unit 3-B: Cylinder Blocks and Liners

Academic and Workplace Skills

Obj. #	Task	Icon	Skill	Sub Skill	Description
6	Pressure test a cylinder block (JS-1)	📚	Reading	Functional reading	Follow written instructions Use content area vocabulary
		✏	Writing	Functional writing	Complete forms and records
		💡	Critical thinking	Cognitive activities	Collect/record information Identify critical elements/issues Draw conclusions
		💼	Employability	Job acquisition/ development	Master specific job task/procedure Practice good work habits/attitudes Develop self confidence/esteem
7	Disassemble and clean a cylinder block (JS-2)	📚	Reading	Functional reading	Follow written instructions Use content area vocabulary
		✏	Writing	Functional writing	Complete forms and records
		💡	Critical thinking	Cognitive activities	Collect/record information Identify critical elements/issues Draw conclusions
		💼	Employability	Job acquisition/ development	Master specific job task/procedure Practice good work habits/attitudes Develop self confidence/esteem
8	Inspect a cylinder block (JS-3)	📚	Reading	Functional reading	Follow written instructions Use content area vocabulary
		✏	Writing	Functional writing	Complete forms and records
		💡	Critical thinking	Cognitive activities	Collect/record information Identify critical elements/issues Draw conclusions
		💼	Employability	Job acquisition/ development	Master specific job task/procedure Practice good work habits/attitudes Develop self confidence/esteem

Basic Skills Matrix

Unit 3–B: Cylinder Blocks and Liners (cont.)

Academic and Workplace Skills

Obj. #	Task	Icon	Skill	Sub Skill	Description
9	Install new camshaft bushings (JS-4)		Reading	functional reading	Follow written instructions Use content area vocabulary
			Writing	Functional writing	Complete forms and records
		?	Critical thinking	Cognitive activities	Collect/record information Identify critical elements/issues Draw conclusions
			Employability	Job acquisition/ development	Master specific job task/procedure Practice good work habits/attitudes Develop self confidence/esteem
10	Clean and inspect cylinder bores (JS-5)		Reading	Functional reading	Follow written instructions Use content area vocabulary
			Writing	Functional writing	Complete forms and records
			Math	Functional math	Make measurements
		?	Critical thinking	Cognitive activities	Collect/record information Identify critical elements/issues Draw conclusions
			Employability	Job acquisition/ development	Master specific job task/procedure Practice good work habits/attitudes Develop self confidence/esteem
11	Install cylinder liners and set liner protrusion (JS-6)		Reading	Functional reading	Follow written instructions Use content area vocabulary
			Writing	Functional writing	Complete forms and records
			Math	Functional math	Make measurements
		?	Critical thinking	Cognitive activities	Collect/record information Identify critical elements/issues Draw conclusions
			Employability	Job acquisition/ development	Master specific job task/procedure Practice good work habits/attitudes Develop self confidence/esteem

Unit 4-B: Crankshafts and Bearings

Academic and Workplace Skills					
Obj. #	**Objective**	**Icon**	**Skill**	**Sub Skill**	**Description**
15	Remove, clean, and inspect a crankshaft (JS-1)	📚	Reading	Functional reading	Follow written instructions Use content area vocabulary
		✏	Writing	Functional writing	Complete forms and records
		🔢	Math	Data analysis and display	Collect/record data
				Functional math	Calculate measurements taken from measuring devices
		⚗	Science	General science	Use scientific instruments
		💡	Critical thinking	Cognitive activities	Collect/record information Identify critical elements/issues
		💼	Employability	Job acquisition/ development	Master specific job task/procedure Practice good work habits/attitudes Develop self confidence/esteem
16	Install main bearings and crankshaft (JS-2)	📚	Reading	Functional reading	Follow written instructions Use content area vocabulary
		✏	Writing	Functional writing	Complete forms and records
		🔢	Math	Data analysis and display	Collect/record data
				Functional math	Calculate measurements taken from measuring devices
		⚗	Science	General science	Use scientific instruments
		💡	Critical thinking	Cognitive activities	Collect/record information Identify critical elements/issues
		💼	Employability	Job acquisition/ development	Master specific job task/procedure Practice good work habits/attitudes Develop self confidence/esteem

Basic Skills Matrix

Unit 4–B: Crankshafts and Bearings (cont.)

Academic and Workplace Skills					
Obj. #	**Task**	**Icon**	**Skill**	**Sub Skill**	**Description**
17	Perform an in-frame bearing roll-in (JS-3)		Reading	Functional reading	Follow written instructions Use content area vocabulary
			Writing	Functional writing	Complete forms and records
			Math	Data analysis and display	Collect/record data
				Functional math	Calculate measurements taken from measuring devices
			Science	General science	Use scientific instruments
			Critical thinking	Cognitive activities	Collect/record information Identify critical elements/issues
			Employability	Job acquisition/ development	Master specific job task/procedure Practice good work habits/attitudes Develop self confidence/esteem
18	Inspect viscous vibration damper/ harmonic balancer (JS-4)		Reading	Functional reading	Follow written instructions Use content area vocabulary
			Writing	Functional writing	Complete forms and records
			Math	Data analysis and display	Collect/record data
				Functional math	Calculate measurements taken from measuring devices
			Science	General science	Use scientific instruments
			Critical thinking	Cognitive activities	Collect/record information Identify critical elements/issues
			Employability	Job acquisition/ development	Master specific job task/procedure Practice good work habits/attitudes Develop self confidence/esteem

Unit 4-B: Crankshafts and Bearings (cont.)

Academic and Workplace Skills					
Obj. #	**Task**	**Icon**	**Skill**	**Sub Skill**	**Description**
19	Inspect bonded vibration damper/ harmonic balancer (JS-5)	📚	Reading	Functional reading	Follow written instructions Use content area vocabulary
		✏	Writing	Functional writing	Complete forms and records
		🔢	Math	Data analysis and display	Collect/record data
				Functional math	Calculate measurements taken from measuring devices
		🧪	Science	General science	Use scientific instruments
		❓	Critical thinking	Cognitive activities	Collect/record information Identify critical elements/issues
		👷	Employability	Job acquisition/ development	Master specific job task/procedure Practice good work habits/attitudes Develop self confidence/esteem
20	Inspect flywheel (JS-6)	📚	Reading	Functional reading	Follow written instructions Use content area vocabulary
		✏	Writing	Functional writing	Complete forms and records
		🔢	Math	Data analysis and display	Collect/record data
				Functional math	Calculate measurements taken from measuring devices
		🧪	Science	General science	Use scientific instruments
		❓	Critical thinking	Cognitive activities	Collect/record information Identify critical elements/issues
		👷	Employability	Job acquisition/ development	Master specific job task/procedure Practice good work habits/attitudes Develop self confidence/esteem

Basic Skills Matrix

Unit 5-B: Pistons and Connecting Rods

Academic and Workplace Skills					
Obj. #	**Objective**	**Icon**	**Skill**	**Sub Skill**	**Description**
16	Remove, dissassemble, and inspect a piston and connecting rod assembly (JS-1)	📚	Reading	Functional reading	Follow written instructions Use content area vocabulary
		✎	Writing	Functional writing	Complete forms and records
		🔢	Math	Data analysis and display	Collect/record data
		⚗	Science	General science	Use scientific instruments
		💡	Critical thinking	Cognitive activities	Collect/record information Identify critical elements/issues
		⛑	Employability	Job acquisition/ development	Master specific job task/procedure Practice good work habits/attitudes Develop self confidence/esteem
17	Measure piston-to-cylinder wall clearance and ring end gap (JS-2)	📚	Reading	Functional reading	Follow written instructions Use content area vocabulary
		✎	Writing	Functional writing	Complete forms and records
		🔢	Math	Data analysis and display	Collect/record data
		💡	Critical thinking	Cognitive activities	Collect/record information Identify critical elements/issues
		⛑	Employability	Job acquisition/ development	Master specific job task/procedure Practice good work habits/attitudes Develop self confidence/esteem
18	Assemble and install piston and connecting rod assembly (JS-3)	📚	Reading	Functional reading	Follow written instructions Use content area vocabulary
		✎	Writing	Functional writing	Complete forms and records
		💡	Critical thinking	Cognitive activities	Identify critical elements/issues
		⛑	Employability	Job acquisition/ development	Master specific job task/procedure Practice good work habits/attitudes Develop self confidence/esteem

Basic Skills Matrix

Unit 6-B: Camshafts, Trains, and Timing

Academic and Workplace Skills

Obj. #	Task	Icon	Skill	Sub Skill	Description
14	Remove, clean, and inspect a camshaft (JS-1)	📚	Reading	Functional reading	Follow written instructions Use content area vocabulary
		✎	Writing	Functional writing	Complete forms and records
		🔢	Math	Data analysis and display	Collect/record data
				Functional math	Calculate measurements taken from measuring devices
		⚗	Science	General science	Use scientific instruments
		💡	Critical thinking	Cognitive activities	Collect/record information Identify critical elements/issues
		👷	Employability	Job acquisition/ development	Master specific job task/procedure Practice good work habits/attitudes Develop self confidence/esteem
15	Remove, inspect, and install cam bushings (JS-2)	📚	Reading	Functional reading	Follow written instructions Use content area vocabulary
		✎	Writing	Functional writing	Complete forms and records
		🔢	Math	Data analysis and display	Collect/record data
				Functional math	Calculate measurements taken from measuring devices
		⚗	Science	General science	Use scientific instruments
		💡	Critical thinking	Cognitive activities	Collect/record information Identify critical elements/issues
		👷	Employability	Job acquisition/ development	Master specific job task/procedure Practice good work habits/attitudes Develop self confidence/esteem

Basic Skills Matrix

Unit 6–B: Camshafts, Trains, and Timing (cont.)

Academic and Workplace Skills					
Obj. #	**Task**	**Icon**	**Skill**	**Sub Skill**	**Description**
16	Install a camshaft and set cam timing (JS-3)		Reading	Functional reading	Follow written instructions Use content area vocabulary
			Writing	Functional writing	Complete forms and records
			Math	Data analysis and display	Collect/record data
			Critical thinking	Cognitive activities	Collect/record information Identify critical elements/issues
			Employability	Job acquisition/ development	Master specific job task/procedure Practice good work habits/attitudes Develop self confidence/esteem

Unit 7-B: Cylinder Head Assemblies

Academic and Workplace Skills					
Obj. #	**Task**	**Icon**	**Skill**	**Sub Skill**	**Description**
11	Locate and label intake and exhaust valves (AS-1)		Reading	Functional reading	Follow written instructions Interpret graphics and symbols Use content area vocabulary
			Writing	Composition	Construct graphics and symbols
12	Clean and inspect a cylinder head (JS-1)		Reading	Functional reading	Follow written instructions Use content area vocabulary
			Writing	Functional writing	Complete forms and records
			Math	Functional math	Calculate measurements taken from measuring devices
			Science	General science	Use scientific instruments
			Critical thinking	Cognitive activities	Collect/record information Identify critical elements/issues
			Employability	Job acquisition/ development	Master specific job task/procedure Practice good work habits/attitudes Develop self confidence/esteem
13	Recondition a cylinder head (JS-2)		Reading	Functional reading	Follow written instructions Use content area vocabulary
			Writing	Functional writing	Complete forms and records
			Math	Functional math	Calculate measurements taken from measuring devices
			Science	General science	Use scientific instruments
			Critical thinking	Cognitive activities	Collect/record information Identify critical elements/issues
			Employability	Job acquisition/ development	Master specific job task/procedure Practice good work habits/attitudes Develop self confidence/esteem

Basic Skills Matrix

Unit 7–B: Cylinder Head Assemblies (cont.)

Academic and Workplace Skills					
Obj. #	**Task**	**Icon**	**Skill**	**Sub Skill**	**Description**
14	Install a cylinder head assembly and adjust valves (JS-3)	●	Reading	Functional reading	Follow written instructions Use content area vocabulary
		●	Writing	Functional writing	Complete forms and records
		●	Math	Functional math	Calculate measurements taken from measuring devices
		●	Critical thinking	Cognitive activities	Identify critical elements/issues
		●	Employability	Job acquisition/ development	Master specific job task/procedure Practice good work habits/attitudes Develop self confidence/esteem

Unit 8-B: Air Induction and Exhaust Systems

Academic and Workplace Skills					
Obj. #	**Task**	**Icon**	**Skill**	**Sub Skill**	**Description**
14	Inspect and test air induction system (JS-1)		Reading	Functional reading	Follow written instructions Use content area vocabulary
			Writing	Functional writing	Complete forms and records
			Math	Functional math	Calculate measurements taken from measuring devices
			Science	General science	Use scientific instruments
			Critical thinking	Cognitive activities	Collect/record information Identify critical elements/issues
			Employability	Job acquisition/ development	Master specific job task/procedure Practice good work habits/attitudes Develop self confidence/esteem
15	Inspect and service turbo/supercharger and related components (JS-2)		Reading	Functional reading	Follow written instructions Use content area vocabulary
			Writing	Functional writing	Complete forms and records
			Math	Functional math	Calculate measurements taken from measuring devices
			Critical thinking	Cognitive activities	Collect/record information Identify critical elements/issues
			Employability	Job acquisition/ development	Master specific job task/procedure Practice good work habits/attitudes Develop self confidence/esteem

Basic Skills Matrix

Unit 8–B: Air Induction and Exhaust Systems (cont.)

Academic and Workplace Skills					
Obj. #	**Task**	**Icon**	**Skill**	**Sub Skill**	**Description**
16	Clean and test jacket water intercooler (JS-3)		Reading	Functional reading	Follow written instructions Use content area vocabulary
			Writing	Functional writing	Complete forms and records
			Math	Functional math	Calculate measurements taken from measuring devices
			Science	General science	Use scientific instruments
			Critical thinking	Cognitive activities	Collect/record information Identify critical elements/issues
			Employability	Job acquisition/ development	Master specific job task/procedure Practice good work habits/attitudes Develop self confidence/esteem
17	Clean and test air-to-air intercooler (JS-4)		Reading	Functional reading	Follow written instructions Use content area vocabulary
			Writing	Functional writing	Complete forms and records
			Math	Functional math	Calculate measurements taken from measuring devices
			Science	General science	Use scientific instruments
			Critical thinking	Cognitive activities	Collect/record information Identify critical elements/issues
			Employability	Job acquisition/ development	Master specific job task/procedure Practice good work habits/attitudes Develop self confidence/esteem

Unit 8–B: Air Induction and Exhaust Systems (cont.)

Academic and Workplace Skills

Obj. #	Task	Icon	Skill	Sub Skill	Description
18	Inspect and test exhaust system (JS-5)		Reading	Functional reading	Follow written instructions Use content area vocabulary
			Writing	Functional writing	Complete forms and records
			Math	Functional math	Calculate measurements taken from measuring devices
			Science	General science	Use scientific instruments
			Critical thinking	Cognitive activities	Collect/record information Identify critical elements/issues
			Employability	Job acquisition/ development	Master specific job task/procedure Practice good work habits/attitudes Develop self confidence/esteem
19	Inspect starting preheater controls (JS-6)		Reading	Functional reading	Follow written instructions Use content area vocabulary
			Writing	Functional writing	Complete forms and records
			Critical thinking	Cognitive activities	Collect/record information Identify critical elements/issues
			Employability	Job acquisition/ development	Master specific job task/procedure Practice good work habits/attitudes Develop self confidence/esteem
20	Test starting fluid system and controls (JS-7)		Reading	Functional reading	Follow written instructions Use content area vocabulary
			Writing	Functional writing	Complete forms and records
			Critical thinking	Cognitive activities	Collect/record information Identify critical elements/issues
			Employability	Job acquisition/ development	Master specific job task/procedure Practice good work habits/attitudes Develop self confidence/esteem

Basic Skills Matrix

Unit 9–B: Engine Brakes and Retarders

Academic and Workplace Skills					
Obj. #	**Task**	**Icon**	**Skill**	**Sub Skill**	**Description**
16	Remove, inspect, install, and adjust a Jacobs engine brake (JS-1)		Reading	Functional reading	Follow written instructions Use content area vocabulary
			Writing	Functional writing	Complete forms and records
			Critical thinking	Cognitive activities	Collect/record information Identify critical elements/issues
			Employability	Job acquisition/ development	Master specific job task/procedure Practice good work habits/attitudes Develop self confidence/esteem
17	Check operation of a BrakeSaver® (JS-2)		Reading	Functional reading	Follow written instructions Use content area vocabulary
			Writing	Functional writing	Complete forms and records
			Critical thinking	Cognitive activities	Collect/record information Identify critical elements/issues
			Employability	Job acquisition/ development	Master specific job task/procedure Practice good work habits/attitudes Develop self confidence/esteem
18	Check operation of an exhaust brake (JS-3)		Reading	Functional reading	Follow written instructions Use content area vocabulary
			Writing	Functional writing	Complete forms and records
			Critical thinking	Cognitive activities	Identify critical elements/issues
			Employability	Job acquisition/ development	Master specific job task/procedure Practice good work habits/attitudes Develop self confidence/esteem
19	Remove, clean, and reinstall an exhaust brake (JS-4)		Reading	Functional reading	Follow written instructions Use content area vocabulary
			Writing	Functional writing	Complete forms and records
			Critical thinking	Cognitive activities	Identify critical elements/issues
			Employability	Job acquisition/ development	Master specific job task/procedure Practice good work habits/attitudes Develop self confidence/esteem

Unit 9-B: Engine Brakes and Retarders (cont.)

Academic and Workplace Skills

Obj. #	Task	Icon	Skill	Sub Skill	Description
20	Check operation of a driveline retarder (JS-5)	📚	Reading	Functional reading	Follow written instructions Use content area vocabulary
		✏	Writing	Functional writing	Complete forms and records
		💡	Critical thinking	Cognitive activities	Identify critical elements/issues
		⛑	Employability	Job acquisition/ development	Master specific job task/procedure Practice good work habits/attitudes Develop self confidence/esteem

Basic Skills Matrix

Section C — Fuel Systems

Unit 1-C: Basic Fuel Systems and Components

Academic and Workplace Skills					
Obj. #	**Task**	**Icon**	**Skill**	**Sub Skill**	**Description**
18	Trace fuel flow through basic fuel systems (AS-1)		Reading	Functional reading	Follow written instructions Interpret graphics and symbols Use content area vocabulary
			Math	Data analysis/ and display	Interpret plans/blueprints
			Critical thinking	Cognitive activities	Analyze/synthesize information Identify/analyze underlying assumptions Draw conclusions Predict results/outcomes
19	Check fuel level, quality and consumption (JS-1)		Reading	Functional reading	Follow written instructions Use content area vocabulary
			Writing	Functional writing	Complete forms and records
			Math	Operation and calculation	Calculate with whole numbers Calculate with fractions Calculate with decimals Solve formulae and equations
				Math application	Solve time/rate/distance problems
				Data analysis and display	Collect/record data
				Functional math	Make measurements
			Science	Physical science	Investigate forms/changes of matter
			Critical thinking	Cognitive activities	Collect/record information Identify critical elements/issues
			Employability	Job acquisition/ development	Master specific job task/procedure Practice good work habits/attitudes Develop self confidence/esteem

Unit 1–C: Basic Fuel Systems and Components (cont.)

Academic and Workplace Skills					
Obj. #	**Task**	**Icon**	**Skill**	**Sub Skill**	**Description**
20	Inspect and service basic fuel supply components (JS-2)	📚	Reading	Functional reading	Follow written instructions Use content area vocabulary
		✏	Writing	Functional writing	Complete forms and records
		💡	Critical thinking	Cognitive activities	Collect/record information Identify critical elements/issues
		⛑	Employability	Job acquisition/ development	Master specific job task/procedure Practice good work habits/attitudes Develop self confidence/esteem

Basic Skills Matrix

Unit 2–C: Mechanical Fuel Injection Diagnosis and Repair

Academic and Workplace Skills					
Obj. #	**Task**	**Icon**	**Skill**	**Sub Skill**	**Description**
24	Isolate, remove, test, rebuild or replace, and reinstall injection nozzles (JS-1)		Reading	Functional reading	Follow written instructions Use content area vocabulary
			Writing	Functional writing	Complete forms and records
			Science	General science	Use scientific instruments
			Critical thinking	Cognitive activities	Collect/record information Identify critical elements/issues Draw conclusions
			Employability	Job acquisition/ development	Master specific job task/procedure Practice good work habits/attitudes Develop self confidence/esteem
25	Isolate, remove, test, and reinstall or replace mechanical unit injectors (JS-2)		Reading	Functional reading	Follow written instructions Use content area vocabulary
			Writing	Functional writing	Complete forms and records
			Science	General science	Use scientific instruments
			Critical thinking	Cognitive activities	Collect/record information Identify critical elements/issues Draw conclusions
			Employability	Job acquisition/ development	Master specific job task/procedure Practice good work habits/attitudes Develop self confidence/esteem
26	Inspect, test, adjust, and time a distributor-type (rotary) injection pump; determine needed repairs (JS-3)		Reading	Functional reading	Follow written instructions Use content area vocabulary
			Writing	Functional writing	Complete forms and records
			Critical thinking	Cognitive activities	Collect/record information Identify critical elements/issues Draw conclusions
			Employability	Job acquisition/ development	Master specific job task/procedure Practice good work habits/attitudes Develop self confidence/esteem

Unit 2-C: Mechanical Fuel Injection Diagnosis and Repair (cont.)

Academic and Workplace Skills

Obj. #	Task	Icon	Skill	Sub Skill	Description
27	Inspect, test, adjust, and time an in-line injection pump; determine needed repairs (JS-4)	📚	Reading	Functional reading	Follow written instructions Use content area vocabulary
		✏	Writing	Functional writing	Complete forms and records
		💡	Critical thinking	Cognitive activities	Collect/record information Identify critical elements/issues Draw conclusions
		⛑	Employability	Job acquisition/ development	Master specific job task/procedure Practice good work habits/attitudes Develop self confidence/esteem
28	Inspect, test, and adjust a PT injection pump and time the injectors; determine needed repairs (JS-5)	📚	Reading	Functional reading	Follow written instructions Use content area vocabulary
		✏	Writing	Functional writing	Complete forms and records
		💡	Critical thinking	Cognitive activities	Collect/record information Identify critical elements/issues Draw conclusions
		⛑	Employability	Job acquisition/ development	Master specific job task/procedure Practice good work habits/attitudes Develop self confidence/esteem

Basic Skills Matrix

Unit 3–C: Electronic Fuel Injection Diagnosis and Repair

Academic and Workplace Skills					
Obj. #	**Task**	**Icon**	**Skill**	**Sub Skill**	**Description**
13	Inspect and test power and ground circuits and connections; determine needed repairs (JS-1)	📚	Reading	Functional reading	Follow written instructions Use content area vocabulary
		✎	Writing	Functional writing	Complete forms and records
		⚗	Science	General science	Use scientific instruments
		💡	Critical thinking	Cognitive activities	Collect/record information Identify critical elements/issues Identify underlying causes Draw conclusions
		👷	Employability	Job acquisition/ development	Master specific job task/procedure Practice good work habits/attitudes Develop self confidence/esteem
14	Check diagnostic trouble codes using scan tools and technical information; determine needed repairs (JS-2)	📚	Reading	Functional reading	Follow written instructions Use content area vocabulary
		✎	Writing	Functional writing	Complete forms and records
		⚗	Science	General science	Use scientific instruments
		💡	Critical thinking	Cognitive activities	Collect/record information Identify critical elements/issues Identify underlying causes Draw conclusions
		👷	Employability	Job acquisition/ development	Master specific job task/procedure Practice good work habits/attitudes Develop self confidence/esteem

Unit 3-C: Electronic Fuel Injection Diagnosis and Repair (cont.)

Academic and Workplace Skills

Obj. #	Task	Icon	Skill	Sub Skill	Description
15	inspect and replace electrical connectors, terminals, seals, and locks (JS-3)	📚	Reading	Functional reading	Follow written instructions Use content area vocabulary
		✏	Writing	Functional writing	Complete forms and records
		⚗	Science	General science	Use scientific instruments
		?	Critical thinking	Cognitive activities	Collect/record information Identify critical elements/issues Identify underlying causes Draw conclusions
		⛑	Employability	Job acquisition/ development	Master specific job task/procedure Practice good work habits/attitudes Develop self confidence/esteem
16	Access engine parameters; monitor or change as requested by customer (JS-4)	📚	Reading	Functional reading	Follow written instructions Use content area vocabulary
		✏	Writing	Functional writing	Complete forms and records
		⚗	Science	General science	Apply computing skills Use scientific instruments
		?	Critical thinking	Cognitive activities	Collect/record information Identify critical elements/issues Identify underlying causes Draw conclusions
		⛑	Employability	Job acquisition/ development	Master specific job task/procedure Practice good work habits/attitudes Develop self confidence/esteem

Basic Skills Matrix

Unit 3–C: Electronic Fuel Injection Diagnosis and Repair (cont.)

Academic and Workplace Skills					
Obj. #	**Task**	**Icon**	**Skill**	**Sub Skill**	**Description**
17	Remove, inspect, and rebuild or replace a fuel transfer pump (JS-5)	📚	Reading	Functional reading	Follow written instructions Use content area vocabulary
		✏	Writing	Functional writing	Complete forms and records
		?	Critical thinking	Cognitive activities	Collect/record information Identify critical elements/issues Draw conclusions
		⛑	Employability	Job acquisition/ development	Master specific job task/procedure Practice good work habits/attitudes Develop self confidence/esteem
18	Remove, inspect, reinstall, and adjust electronic unit injectors; determine needed repairs (JS-6)	📚	Reading	Functional reading	Follow written instructions Use content area vocabulary
		✏	Writing	Functional writing	Complete forms and records
		?	Critical thinking	Cognitive activities	Collect/record information Identify critical elements/issues Draw conclusions
		⛑	Employability	Job acquisition/ development	Master specific job task/procedure Practice good work habits/attitudes Develop self confidence/esteem

Unit 4-C: Emissions

Academic and Workplace Skills					
Obj. #	**Task**	**Icon**	**Skill**	**Sub Skill**	**Description**
11	Check vehicle for presence and operation of emission control devices (JS-1)	📚	Reading	Functional reading	Follow written instructions Use content area vocabulary
		✎	Writing	Functional writing	Complete forms and records
		⚗	Science	General science	Apply computing skills Use scientific instruments
		?	Critical thinking	Cognitive activities	Collect/record information Identify critical elements/issues Draw conclusions
		⛑	Employability	Job acquisition/ development	Master specific job task/procedure Practice good work habits/attitudes Develop self confidence/esteem
12	Check vehicle for fuel type and appropriate application (JS-2)	📚	Reading	Functional reading	Follow written instructions Use content area vocabulary
		✎	Writing	Functional writing	Complete forms and records
		?	Critical thinking	Cognitive activities	Collect/record information Identify critical elements/issues Draw conclusions
		⛑	Employability	Job acquisition/ development	Master specific job task/procedure Practice good work habits/attitudes Develop self confidence/esteem
13	Test vehicle for excessive exhaust smoke (JS-3)	📚	Reading	Functional reading	Follow written instructions Use content area vocabulary
		✎	Writing	Functional writing	Complete forms and records
		⚗	Science	General science	Use scientific instruments Investigate/apply technology
				Physical science	Investigate forms/changes of energy
		?	Critical thinking	Cognitive activities	Collect/record information Identify critical elements/issues Draw conclusions
		⛑	Employability	Job acquisition/ development	Master specific job task/procedure Practice good work habits/attitudes Develop self confidence/esteem

Basic Skills Matrix

Unit 4–C: Emissions (cont.)

Academic and Workplace Skills

Obj. #	Task	Icon	Skill	Sub Skill	Description
14	Check vehicle for noise abatement devices (JS-4)	📚	Reading	Functional reading	Follow written instructions Use content area vocabulary
		✏	Writing	Functional writing	Complete forms and records
		💡	Critical thinking	Cognitive activities	Collect/record information Identify critical elements/issues Draw conclusions
		💼	Employability	Job acquisition/ development	Master specific job task/procedure Practice good work habits/attitudes Develop self confidence/esteem

Section D — Engine Diagnosis and Maintenance

Unit 1-D: General Engine Diagnosis

Academic and Workplace Skills ✓

Obj. #	Task	Icon	Skill	Sub Skill	Description
11	Conduct an operator survey for engine diagnosis (AS-1)	📚	Reading	Reading comprehension	Gain factual information Analyze causes and effect Draw conclusions
				Research/ reference	Use in-book reference tools
				Functional reading	Follow written instructions Use content area vocabulary
		✏	Writing	Research	Take notes
				Functional writing	Complete forms and records
		🗣	Oral communication	Listening	Apply active listening skills Distinguish fact, opinion, and inference Draw conclusions/make generalizations
				Interactive communication	Apply questioning techniques Conduct/receive interviews Communicate with clients/customers/ patients
		💡	Critical thinking	Cognitive activities	Collect/record information Identify critical elements/issues Define a problem Identify underlying causes Analyze/synthesize information Draw conclusions
		⛑	Employability	Job acquisition/ development	Practice good work habits/attitudes Develop self confidence/esteem Deal effectively with customers/clients/ patients
12	Interpret SAE code identifiers (AS-2)	📚	Reading	Reading comprehension	Gain factual information
				Research/ reference	Use in-book reference tools
				Functional reading	Follow written instructions Use content area vocabulary
		💡	Critical thinking	Cognitive activities	Collect/record information
		⛑	Employability	Job acquisition/ development	Practice good work habits/attitudes Develop self confidence/esteem

Basic Skills Matrix

Unit 1-D: General Engine Diagnosis (cont.)

Academic and Workplace Skills					
Obj. #	**Task**	**Icon**	**Skill**	**Sub Skill**	**Description**
13	Check air intake system for restrictions (JS-1)	📚	Reading	Functional reading	Follow written instructions Use content area vocabulary
		✏	Writing	Functional writing	Complete forms and records
		⚗	Science	General science	Use scientific instruments
		💡	Critical thinking	Cognitive activities	Collect/record information Identify critical elements/issues Identify underlying causes Draw conclusions
		⛑	Employability	Job acquisition/ development	Master specific job task/procedure Practice good work habits/attitudes Develop self confidence/esteem
14	Check exhaust back pressure (JS-2)	📚	Reading	Functional reading	Follow written instructions Use content area vocabulary
		✏	Writing	Functional writing	Complete forms and records
		⚗	Science	General science	Use scientific instruments
		💡	Critical thinking	Cognitive activities	Collect/record information Identify critical elements/issues Draw conclusions
		⛑	Employability	Job acquisition/ development	Master specific job task/procedure Practice good work habits/attitudes Develop self confidence/esteem
15	Check crankcase pressure (JS-3)	📚	Reading	Functional reading	Follow written instructions Use content area vocabulary
		✏	Writing	Functional writing	Complete forms and records
		⚗	Science	General science	Use scientific instruments
		💡	Critical thinking	Cognitive activities	Collect/record information Identify critical elements/issues Draw conclusions
		⛑	Employability	Job acquisition/ development	Master specific job task/procedure Practice good work habits/attitudes Develop self confidence/esteem

Unit 1–D: General Engine Diagnosis (cont.)

Academic and Workplace Skills					
Obj. #	**Task**	**Icon**	**Skill**	**Sub Skill**	**Description**
16	Check oil pressure (JS-4)	📚	Reading	Functional reading	Follow written instructions Use content area vocabulary
		✎	Writing	Functional writing	Complete forms and records
		?	Critical thinking	Cognitive activities	Collect/record information Identify critical elements/issues Draw conclusions
		⛑	Employability	Job acquisition/ development	Master specific job task/procedure Practice good work habits/attitudes Develop self confidence/esteem
17	Load test an engine with a dynamometer (JS-5)	📚	Reading	Functional reading	Follow written instructions Use content area vocabulary
		✎	Writing	Functional writing	Complete forms and records
		⚗	Science	General science	Use scientific instruments
		?	Critical thinking	Cognitive activities	Collect/record information Identify critical elements/issues Draw conclusions
		⛑	Employability	Job acquisition/ development	Master specific job task/procedure Practice good work habits/attitudes Develop self confidence/esteem
18	Locate a misfiring cylinder (JS-6)	📚	Reading	Functional reading	Follow written instructions Use content area vocabulary
		✎	Writing	Functional writing	Complete forms and records
		⚗	Science	General science	Use scientific instruments
		?	Critical thinking	Cognitive activities	Collect/record information Identify critical elements/issues Draw conclusions
		⛑	Employability	Job acquisition/ development	Master specific job task/procedure Practice good work habits/attitudes Develop self confidence/esteem

Unit 1-D: General Engine Diagnosis (cont.)

Academic and Workplace Skills

Obj. #	Task	Icon	Skill	Sub Skill	Description
19	Locate an active fault code (JS-7)		Reading	Functional reading	Follow written instructions Use content area vocabulary
			Writing	Functional writing	Complete forms and records
			Science	General science	Apply computing skills Use scientific instruments
			Critical thinking	Cognitive activities	Collect/record information Identify critical elements/issues Draw conclusions
			Employability	Job acquisition/ development	Master specific job task/procedure Practice good work habits/attitudes Develop self confidence/esteem

Unit 2-D: Preventive Maintenance and Tune-Up

Academic and Workplace Skills

Obj. #	Task	Icon	Skill	Sub Skill	Description
9	Determine maintenance needed for given situations (AS-1)	📚	Reading	Reading comprehension	Gain factual information Distinguish fact, opinion and inference Draw conclusions
				Research/ reference	Use in-book reference tools
				Functional reading	Follow written instructions Use content area vocabulary
		✎	Writing	Language	Use standard grammar, spelling, and capitalization State ideas clearly
				Composition	Compose reports
		💡	Critical thinking	Cognitive activities	Collect/record information Identify critical elements/issues Define a problem Identify underlying causes Analyze/synthesize information Draw conclusions
		⛑	Employability	Job acquisition/ development	Practice good work habits/attitudes Develop self confidence/esteem
10	Interpret maintenance troubleshooting charts (AS-2)	📚	Reading	Reading comprehension	Gain factual information Analyze cause and effect Draw conclusions
				Research/ reference	Use in-book reference tools
				Functional reading	Follow written instructions Use content area vocabulary
		✎	Writing	Language	Use standard grammar, spelling, and capitalization
		💡	Critical thinking	Cognitive activities	Collect/record information Identify critical elements/issues Identify/analyze underlying assumptions
11	Inspect engine coolant level and condition (JS-1)	📚	Reading	Functional reading	Follow written instructions Use content area vocabulary
		✎	Writing	Functional writing	Complete forms and records
		💡	Critical thinking	Cognitive activities	Collect/record information Identify critical elements/issues Draw conclusions
		⛑	Employability	Job acquisition/ development	Master specific job task/procedure Practice good work habits/attitudes Develop self confidence/esteem

Basic Skills Matrix

Unit 2-D: Preventive Maintenance and Tune-Up (cont.)

Academic and Workplace Skills

Obj. #	Task	Icon	Skill	Sub Skill	Description
12	Pressure test coolant system and radiator cap (JS-2)	📚	Reading	Functional reading	Follow written instructions Use content area vocabulary
		✏	Writing	Functional writing	Complete forms and records
		💡	Critical thinking	Cognitive activities	Collect/record information Identify critical elements/issues Draw conclusions
		⛑	Employability	Job acquisition/ development	Master specific job task/procedure Practice good work habits/attitudes Develop self confidence/esteem
13	Take oil sample, and change oil and filter(s) (JS-3)	📚	Reading	Functional reading	Follow written instructions Use content area vocabulary
		✏	Writing	Functional writing	Complete forms and records
		💡	Critical thinking	Cognitive activities	Collect/record information Identify critical elements/issues Draw conclusions
		⛑	Employability	Job acquisition/ development	Master specific job task/procedure Practice good work habits/attitudes Develop self confidence/esteem
14	Inspect and test indicator system components (JS-4)	📚	Reading	Functional reading	Follow written instructions Use content area vocabulary
		✏	Writing	Functional writing	Complete forms and records
		2 +6 4 5	Math	Data analysis and display	Collect/record data
		💡	Critical thinking	Cognitive activities	Collect/record information Identify critical elements/issues Define a problem Identify underlying causes Analyze/synthesize information Identify/analyze underlying assumptions Draw conclusions
		⛑	Employability	Job acquisition/ development	Master specific job task/procedure Practice good work habits/attitudes Develop self confidence/esteem

Unit 2–D: Preventive Maintenance and Tune-Up (cont.)

Academic and Workplace Skills

Obj. #	Task	Icon	Skill	Sub Skill	Description
15	Perform a daily preventive maintenance check (JS-5)		Reading	Functional reading	Follow written instructions Use content area vocabulary
			Writing	Functional writing	Complete forms and records
		?	Critical thinking	Cognitive activities	Collect/record information Identify critical elements/issues Draw conclusions
			Employability	Job acquisition/ development	Master specific job task/procedure Practice good work habits/attitudes Develop self confidence/esteem
16	Perform a mileage preventive maintenance check (JS-6)		Reading	Functional reading	Follow written instructions Use content area vocabulary
			Writing	Functional writing	Complete forms and records
		?	Critical thinking	Cognitive activities	Collect/record information Identify critical elements/issues Draw conclusions
			Employability	Job acquisition/ development	Master specific job task/procedure Practice good work habits/attitudes Develop self confidence/esteem
17	Perform an engine tune-up (JS-7)		Reading	Functional reading	Follow written instructions Use content area vocabulary
			Writing	Functional writing	Complete forms and records
		?	Critical thinking	Cognitive activities	Collect/record information Identify critical elements/issues Define a problem Identify underlying causes Analyze/synthesize information Identify/analyze underlying assumptions Draw conclusions
			Employment	Job acquisition/ development	Master specific job task/procedure Practice good work habits/attitudes Develop self confidence/esteem

Tools, Equipment, and Materials List

Alphabetical list of tools, equipment, and materials

- All thread (threaded rod)
- Ammeter, inductive
- Barring tool
- Bearing installation tool
- Bench, clean
- Blow-by inspection tool, OEM approved
- Breaker bar
- Brush, bore
- Brush, wire cleaning
- Cam bearing/bushing installation tool
- Cam bearing/bushing removal tool
- Cleaning flux
- Cold tank
- Components, old, for wear and failure analysis
- Compressed air
- Containers to hold small parts
- Containers to collect fluid samples
- Coolant
- Coolant service kit, as recommended
- Crayons, thermomelt, wax
- Crocus cloth
- Cylinder liner installation tool
- Cylinder liner removal tool
- Cylinder liner retainer
- Damper remover
- Degreaser
- Dial test indicator with stand
- Drain pans or other containers
- Drill, air with sanding discs
- Driver, cylinder sleeve/liner
- Dye penetrant
- Dynamometer
- Electrical circuit testing tools
  - Test leads with various tips
  - OEM jumper wires
- Electronic diagnostic equipment, designed or adapted for vehicle
  - Scan tool/digital reader
  - Personal computer with appropriate engine diagnostic software
- Electronic adapters
- Emission analyzer
- Emission probe, tailpipe
- Engine, diesel—to be worked on
- Engine electrical harness
- Engine hoist and adapters
- Engine stand
- Ethylene glycol
- Flashlight
- Flex hone
- Funnel and/or spout
- Gauges, various
  - Ball and hole set
  - Belt tension
  - Bore
  - Cylinder bore set
  - Depth
  - Electrical test, remote
  - Feeler set
  - Fuel pressure
  - Oil pressure
  - Pressure, basic
  - Timing light
  - Oil temperature
  - Water temperature
- Gasket scraper
- Gear puller
- Grease, white
- Hammer, brass
- Hand drill
- Hand tools, technician's common set
- Heel bar
- Hot plate
- Hydrometer, diesel fuel
- Infrared gun
- Injector rocker lever actuator
- Jack, transmission
- Job tickets/work orders—blank forms
- Lifting tool, crankshaft
- Lubricant, assembly
- Manometer
- Magnahelic gauge
- Measuring stick

Tools, Equipment, and Materials List

- Micrometers
  - Depth
  - Outside
  - Inside
- Mineral spirits
- Mirror, hand held extension
- Multimeter
- Oil, clean engine
- Oil, clean fuel or calibrating
- Oil, vegetable
- Opacity meter
- Parts cleaning solution
- Pen, black felt tip
- Petroleum jelly
- Piston ring compressor
- Plastigage
- Pry bar
- Pyrometer, contact
- Ratchet, ½″ drive
- Reamer, injector tube, bevel
- Replacement parts (gaskets, seals, etc.)
- Safety equipment
  - Safety glasses/goggles
  - Protective gloves
  - Hearing protection
- Service manuals
- Shop towels
- Socket, fuel pipe
- Solder, rosin core
- Soldering iron or gun
- Solvent, cleaning or other approved cleaner
- Sponge
- Steam cleaner
- Straight edge
- Tachometer, remote
- Test equipment as specified by mfg.
- Testers
  - Compression, with adapters
  - Nozzle
  - Injector
  - Injector, comparator or calibrator
  - Radiator pressure, with cap
- adapter
- Thermometer, standard and infrared
- Turning tool, crankshaft
- Valve guide servicing equipment
- Valve/seat reconditioning equipment
- Valve spring compressor
- Vise, bench
- Volt-ohmmeter, digital
- Washer, high pressure hot water
- Wire stripping and crimping tool
- Wrench, filter
- Wrench torque

Note: Additional tools, equipment, and materials may be required by the service manual or instructor.

Unit 1-A Engine Operating Principles

Unit Contents

Teacher Components

Teacher Page

Suggested Activities 1A–3

Answers to Assignment Sheets 1A–11

Written Test 1A–13

Answers to Written Test 1A–21

Learning Activities Sheet 1A–23

Teacher Supplement

1—Internet Resources 1A–25

Transparency Masters

1—Compression Ratio 1A–27
2—Two-Stroke Diesel Engine Components 1A–29
3—Four-Stroke Diesel Engine Components 1A–31
4—Four-Stroke Cycle 1A–33
5—Two-Stroke Cycle 1A–35

Student Components

Student Page

Objective Sheet 1A–3

Information Sheet 1A–5

Assignment Sheets

1—Identify Companion Cylinders 1A–17
2—Locate and Record Engine Specifications 1A–19
3—Identify Valve and Piston Position During Each Stroke 1A–23

Job Sheets

1—Locate TDC Compression for #1 Piston 1A–25
2—Measure Bore and Stroke and Compute Engine Displacement . 1A–29

Suggested Activities

Instructional Plan

Preparation

- Read the unit carefully and plan for instruction.
- Review "Teaching Suggestions." Plan for classroom activities.
- Plan your presentation to take advantage of student learning styles and to accommodate special-needs students.
- Prepare classroom. Put up posters and charts and display articles and other references related to this unit.
- Obtain films, videotapes, and other resources to supplement instruction of this unit. See "Resources Used in Developing This Unit" and "Suggested Supplemental Resources" for more information.
- For self-paced instruction, review Learning Activities Sheet. Modify as appropriate to include additional activities and/or resources available in your classroom. Make one copy for each student.
- Make transparencies from the transparency masters included in this unit. These appear in the teacher edition only.

Delivery and Application

Unit Introduction (self-paced instruction)

- Provide student with Learning Activities Sheet and unit of instruction.
- Review unit contents with student.
- Have the student complete the steps in the learning activities sheet.

Unit Introduction (group instruction)

- Provide students with unit of instruction.
- Discuss unit and specific objectives.
- Discuss the information sheet. Implement teaching plan to localize, supplement, and personalize the unit. Reinforce basic academic and workplace skills when applicable.
- Discuss the assignment sheets. Review with students the criteria for evaluation of these activities.

Suggested Activities

- Discuss and demonstrate the job sheets. Make sure all required tools, equipment, and materials are available. Review with students the criteria for evaluation of these activities and the rating scale that will be used to indicate job performance.

Teaching Suggestions

- Consult local businesses about providing short-term resource materials, training aids, or knowledgeable personnel to act as mentors or future guest speakers. Due to work schedules and commitments, these arrangements should be made well in advance. Sources for local business/industry participation might include:
  - — Agricultural/heavy truck/industrial dealerships and/or repair centers
  - — Equipment manufacturers
  - — OEM/Aftermarket parts suppliers
  - — Component rebuilders
  - — Labor union representatives
- Conduct field trip(s) to observe component overhaul and/or engine servicing and repair.
- Divide the class into groups of two or three, and assign each group a research project covering a different aspect of diesel engine application. These projects can be done as either oral or written reports and should have a limit of 5 pages or 10 minutes. Application areas might include:
  - — Industrial (stationary or mobile)
  - — Light-, medium-, or heavy-duty truck
  - — Agricultural
  - — Marine
  - — Military
- Use shop engines to demonstrate the following concepts:
  - — TDC and BDC
  - — Valve location, identification, and operation
  - — Timing mark location
- Review with students the format and use of service manuals to locate specific information.

- Allow students to work in teams of two on the job sheets. This allows more effective equipment usage and provides opportunities for peer tutoring.
- Prior to teaching this unit, prepare selected shop engines for student use in performing the tasks listed in the job sheets. By removing cylinder heads, valve train, etc. ahead of time, you will most efficiently use the time allotted for class/shop activities.

Evaluation

- Make copies of the written test. Add or modify test items as needed. The written test serves as both a pretest and posttest to assist in measuring each student's competency gains.
- Give and evaluate pretest. Modify lesson plan to include additional instruction for those areas where students were deficient.
- Evaluate the assignment sheets. Rate the student using the criteria listed on each assignment sheet. See Answers to Assignment Sheets for correct answers where applicable. If the student's performance is unacceptable, have the student review the appropriate materials and complete the assignment again.
- Evaluate the job sheets. When the student is ready to perform a specific task, obtain a copy of the job sheet which may be found in the student edition. Then observe the student performing the procedure.

  Process evaluation—Place a mark in the box to the left of each designated checkpoint if the student has satisfactorily completed the process step(s) for each checkpoint area. If the student is unable to complete the procedure correctly, have the student review the materials and try again.

  Product evaluation—Once the student has satisfactorily completed the procedure, rate the student product (outcome) using the criteria that are provided as part of the job sheet. If the student's product is unacceptable, have the student review the materials and submit another product for evaluation.

  Two sample performance evaluation keys have been provided below. Many other keys are available. Select one rating (grading scale) that best fits your program needs.

Sample A

4—**Skilled**—Can perform job with no additional training.
3—**Moderately skilled**—Has performed job during training program; limited additional training may be required.
2—**Limited skill**—Has performed job during training program; additional training is required to develop skill.
1—**Unskilled**—Is familiar with process, but is unable to perform job.
0—**No exposure**—No information or practice provided during training program.

Suggested Activities

Sample B

Yes—Can perform job with no additional training.
No—Is unable to perform job satisfactorily.

- Give and evaluate the posttest.
- Meet individually with students to evaluate their progress through this unit of instruction and indicate to them possible areas of improvement.
- Reteach and retest as required.

Resources Used in Developing This Unit

Print Media

- Clark, Elton, et al. *Diesel Fundamentals*. Stillwater, OK: Mid-America Vocational Curriculum Consortium, Inc., 1988.
- Dagel, John F. *Diesel Engine and Fuel System Repair*, 4th ed. Upper Saddle River, NJ: Prentice Hall, 1994.
- *Detroit Diesel Allison, 60 Series Service Manual*. Detroit, MI: General Motors Corp., 1995.
- Espenschied, Roland F. *Diesel Engines*. Athens, GA: American Association for Vocational Instructional Materials, 1990.
- *Fundamentals of Service: Engines*, 7th ed. Moline, IL: Deere and Company, 1991.
- *Rebuild Manual, Cummins Diesel 10 Litre Engines*. Columbus, IN: Cummins Engine Co., 1984.
- Schultz, Erich J. *Diesel Mechanics*, 4th ed. Dallas, TX: Glencoe/McGraw-Hill, 1998.
- *Service Manual, 3176B Diesel Truck Engine*. Peoria, IL: Caterpillar, Inc., 1995.
- *The Engine Book—An Introduction to Diesel Engines*. (#LEBQ 9801) Peoria, IL: Caterpillar, Inc.
- Warren, Larry and John H. Haynes. *Mercedes-Benz Diesel Automotive Repair Manual*. Newbury Park, CA: Haynes Publications, Inc.

Note: Engine service manuals can be ordered through the local dealership.

Suggested Supplemental Resources

Electronic Media

- *Theory and Operation of Diesel Engines, Parts 1 and 2.* (985616 and 985617) Available as booklet, slide set, or audio tape.
- *Basic Combustion and Related Factors.* (3387170) Available as booklet, slide set, or audio tape.
- *Fundamentals of Diesel Engine Operation* (3387909) VHS videotape and student workbook.

The above are available from your local Cummins Engine Company dealer/distributor or call:

Cummins Engine Company Customer Relations
800-345-5654 or 502-453-8549 or for more information call 1-800-DIESELS

- *Diesel Basics* video (STVV DB) or slide/cassette (STSC DB)—Covers the basics of diesel engines, four-stroke cycles, and components. Also presents basic information about Bosch diesel injection pumps, governors, and injection nozzles. Available from:

Robert Bosch Corporation
Training Materials
2740 West 79th Street
Chicago, IL 60652-1784
Phone: 1-800-937-2672 or Fax: 1-312-776-1717

- *Diesel Engine Operation* video (MER-5211-VW). Covers design, construction, and operation of diesel engines. Explains both two-stroke and four-stroke diesel engines. 1993.
- *Diesel Engine* software for IBM 3.5″ (AAVIM-111CSI3-IW). Contains 123 questions. Basic review, testing, printout, random selection, and password lockout.
- *Engine Basics* software for Mac 800K, Color Mac 1.44M, or IBM 3.5". Lessons and quizzes on engine basics, internal combustion engines, diesel engines, cooling systems, and exhaust systems.

The above are available from:

NIMCO
102 Hwy. 81 North
P.O. Box 9
Calhoun, KY 42327-0009
Phone: 1-800-962-6662 or Fax: 1-502-273-5844
http://www.nimcoinc.com

Suggested Activities

- *Diesel Mechanics*, set of 6 slides-on-videotape. (#472X-V3)—Examine the external components and disassembly of a Cummins NH-855 diesel engine.

- *Diesel Preventive Maintenance* VHS videocassette set. Includes 5 cassettes and study guides—one for each of the following: Fuel systems, air system, lubricating system, cooling system, and electrical system.

- *Diesel Operation and Maintenance*, set of 4 slides-on-videotape. (#475X-V3)—Covers a. Diesel fundamentals, b. Diesel components and functions, c. Diesel fuel and lubrication, and d. Basic maintenance procedures.

  The above are available from:

  Thomson Learning
  P.O. Box 6904
  Florence, KY 41022-6904
  Phone: 1-800-354-9706
  E-mail: esales@thomsonlearning.com
  http://www.thomsonlearning.com

- *ABC's of Diesel Engines* videotape (25STV 0123).

- *The Two Stroke Advantage* videotape (25STV 0162).

  The above are available from your local Detroit Diesel distributor/dealer or order from the following:

  Robot Literature Distribution
  12085 Dixie
  Redford, MI 48239
  Phone: 1-313-255-9300 or Fax: 1-313-255-7680

- *FOS Engines* set of 306 slides.

  Available from:

  John Deere Publishing
  5440 Corporate Park Drive
  Davenport, IA 52807
  1-800-522-7448
  http://www.deere.com

Suggested Activities

- *Diesel Engine Series*
  - *Diesel Engine Technology* 5211, 24 minutes
  - *Diesel Engine Teardown* 5212, 25 minutes

These videotapes feature live action as well as computer animation and are available from:

Echoscan Inc.
2930 Pine Ave., Suite 5263
Niagara Falls, NY 14301
http://www.echoscaninc.com
E-mail: sales@echoscaninc.com

Answers to Assignment Sheets

Assignment Sheet 1

Identify Companion Cylinders

1. $\frac{1647}{2538}$ = 1 & 2, 6 & 5, 4 & 3, 7 & 8
2. $\frac{152}{634}$ = 1 & 6, 5 & 3, 2 & 4
3. $\frac{1354}{6872}$ = 1 & 6, 3 & 8, 5 & 7, 4 & 2

Assignment Sheet 2

Locate and Record Engine Specifications

Answers will vary depending on engine used.

Assignment Sheet 3

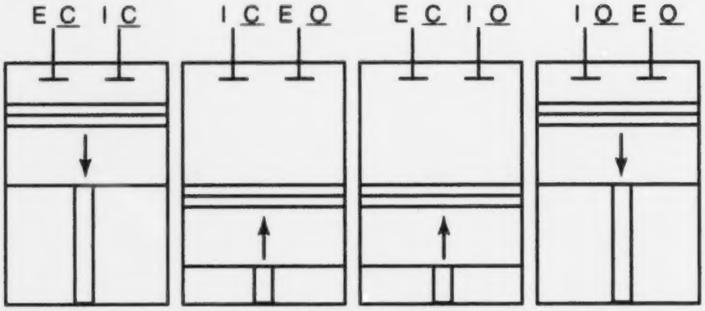
Identify Valve and Piston Position During Each Stroke

Cylinder #2
Intake valve **Closed**
Exhaust valve **Open**
Piston moving **Up**
Exhaust Stroke

Cylinder #3
Exhaust valve **Closed**
Intake valve **Open**
Piston moving **Up**
Compression Stroke

Cylinder #4
Intake valve **Open**
Exhaust valve **Open**
Piston moving **Down**
Intake Stroke

Figure 1



Power Exhaust Compression Intake

Written Test

Name ______________________________________

Date ____________________________ Score __________

Objective 1

Match terms related to engine operating principles with their definitions. Definitions continue on the next page.

1. Accessory
2. Bottom Dead Center
3. Clearance volume
4. Combustion
5. Companion cylinders
6. Component
7. Compression
8. Compression ratio
9. Cycle
10. Cylinder volume
11. Displacement
12. Engine speed
13. Firing order
14. Horsepower
15. Integral
16. Overspeed
17. Power control
18. Precombustion chamber
19. Pump
20. Reciprocating motion
21. Rotary motion
22. Scavenging
23. Stroke
24. System
25. Temperature
26. Thermostat
27. Top Dead Center
28. Torque
29. Valve
30. Valve overlap

_____ a. Location of the piston at its highest point of travel

_____ b. Using the intake of fresh air to clear exhaust gases from the cylinder

_____ c. Crankshaft revolutions per minute (RPM)

_____ d. Period of time, measured in crankshaft degrees, that both the intake and exhaust valves are open

_____ e. Location of the piston at its lowest point of travel

_____ f. Reducing the volume of the trapped air in the cylinder by pushing the piston upward

_____ g. Small cavity in the cylinder head of some diesel engines where fuel ignition and combustion first occur

_____ h. Distance the piston travels from TDC to BDC, or from BDC to TDC

_____ i. Burning the air/fuel mixture to produce heat

_____ j. Measure of heat intensity

_____ k. Component that is not always essential to the operation of the engine

_____ l. Device that transfers fluids or gases using suction or pressure or both

_____ m. Sequence in which the cylinders, beginning with number 1 cylinder, deliver their power stroke

_____ n. To move physically out of position or to take the place of

_____ o. Measurement of twisting force

_____ p. When an engine exceeds its governed maximum no-load RPM's

_____ q. Automatic device for regulating temperature

_____ r. Movement in a circular manner

_____ s. Measurement of an engine's power

_____ t. Device for sealing the intake and/or exhaust ports in a cylinder head

Objective 2

Match basic engine systems with their functions.

1. Air intake and exhaust system
2. Cooling system
3. Electrical charging system
4. Electrical starting system
5. Electronic control system
6. Engine braking system
7. Fuel system
8. Lubrication system

_____ a. Uses the engine's power to help slow the vehicle

_____ b. Provides fuel storage and delivers fuel to engine using mechanical and/or electronic components

_____ c. Controls and powers electric motor used to start the engine

_____ d. Reduces friction by providing lubrication around and between moving parts or contact points within engine; helps transfer heat to cool the engine; and cleans engine by removing contaminants

_____ e. Circulates either air only or air and liquid to transfer heat of combustion and friction away from engine to prevent engine damage

_____ f. Provides cleaned, pressurized, and cooled air to the engine and then directs exhaust gases to accessory equipment and atmosphere

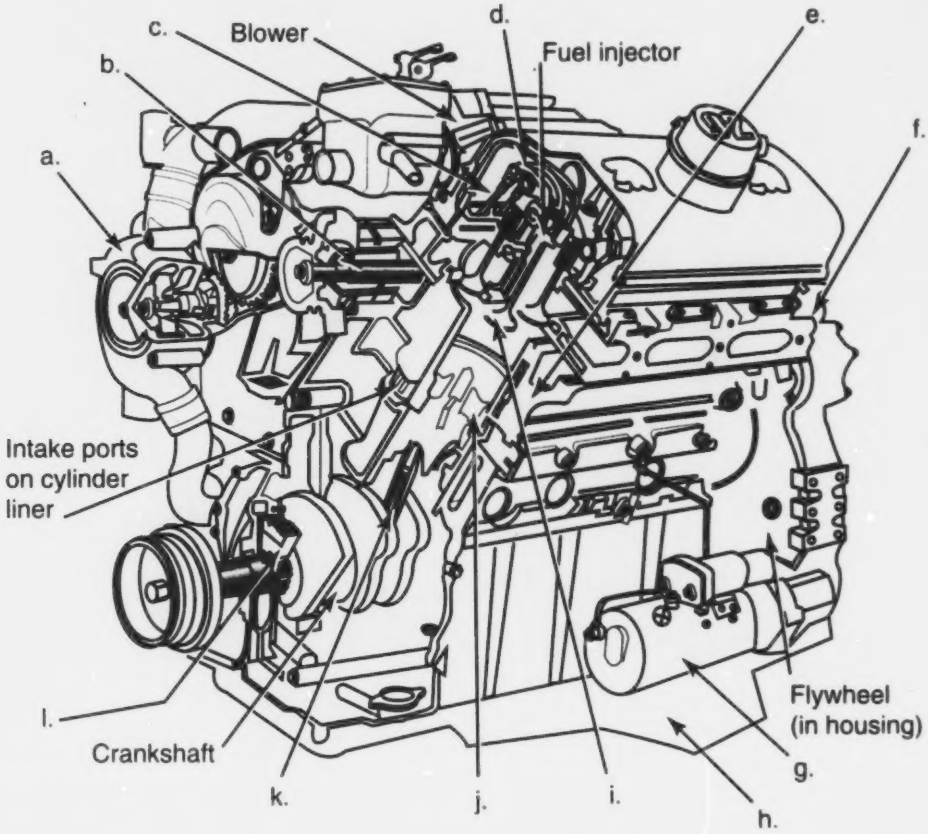
_____ g. Produces, controls, and monitors electrical current needed while vehicle is running; also recharges the storage batteries

Written Test

Objective 3

Identify basic engine components on two-stroke and four-stroke diesel engines. Write your answers in the blanks provided.

Figure 1—Two-stroke diesel engine



c.
Blower
d.
Fuel injector
e.
b.
f.
a.
Intake ports on cylinder liner
Flywheel (in housing)
l.
Crankshaft
g.
k.
j.
i.
h.

a. ____________________

b. ____________________

c. ____________________

d. ____________________

e. ____________________

f. ____________________

g. ____________________

h. ____________________

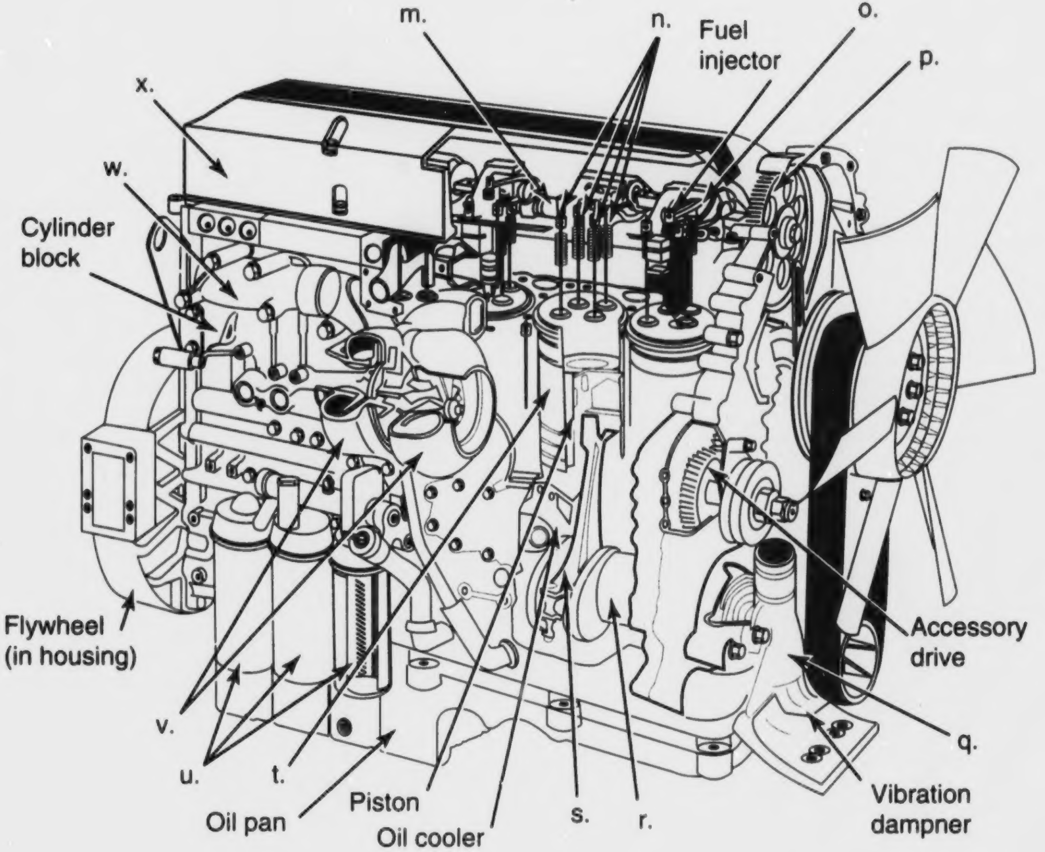
i. ____________________

j. ____________________

k. ____________________

l. ____________________

Figure 2—Four-stroke diesel engine


m.
n.
Fuel injector
o.
p.
x.
w.
Cylinder block
Flywheel (in housing)
Accessory drive
q.
Vibration dampner
v.
u.
t.
Oil pan
Piston
Oil cooler
s.
r.

m. ____________________ n. ____________________

o. ____________________ p. ____________________

q. ____________________ r. ____________________

s. ____________________ t. ____________________

u. ____________________ v. ____________________

w. ____________________ x. ____________________

Written Test

Objective 4

Match the basic internal engine components with their functions.

1. Camshaft
2. Camshaft gear
3. Connecting rod
4. Coolant passage
5. Crankshaft
6. Crankshaft gear
7. Cylinder
8. Cylinder block
9. Cylinder head
10. Exhaust valve
11. Flywheel
12. Intake valve
13. Oil cooler
14. Oil pan
15. Oil pump
16. Piston
17. Push rod or push tube
18. Rocker arm
19. Valve lifter
20. Vibration damper

_____ a. Attached to the camshaft and driven by the crankshaft gear

_____ b. Drives the camshaft gear or idler gear

_____ c. Opens a port in the cylinder head to allow the spent exhaust gases to be forced from the cylinder

_____ d. Hollow space in either the cylinder head or block through which coolant circulates

_____ e. Converts heat energy into reciprocating motion

_____ f. Heat exchanger that cools and regulates oil temperature

_____ g. Shaft with eccentric lobes that controls valves, and in some designs, also controls the injectors

_____ h. Pressurizes oil to circulate it to rotating and reciprocating parts

_____ i. Reservoir for the engine oil

_____ j. Connects the piston to the crankshaft and transmits the reciprocating motion to the crankshaft

_____ k. Iron or aluminum alloy casting which houses the cylinders, water and lubrication passages, crankshaft, and in some designs, the camshaft

_____ l. Rides on the cam lobe; also known as a cam follower

_____ m. Machined casting bolted to the top of the cylinder block

_____ n. Opens a port in the cylinder head to allow the fresh air charge to be drawn into the cylinder

_____ o. Machined hole in the cylinder block that contains the piston

_____ p. Attaches to the end of the crankshaft; stores momentum and smoothes out firing pulses

_____ q. Transfers motion from the push rod to the valve

Written Test

Objective 5

Distinguish between gasoline and diesel engines by labeling gasoline engine characteristics with a "G" and diesel engine characteristics with a "D."

_____ a. Fuel is injected directly into the combustion chamber.

_____ b. Compression ignition

_____ c. Lighter construction with extensive use of alloys and aluminum

_____ d. High compression ratio (16–22:1)

_____ e. Heavy cast iron and forged steel construction

_____ f. Electric spark ignition

_____ g. Fresh air is mixed with fuel first, then brought into the combustion chamber.

_____ h. Burns lower grade fuel oil

_____ i. Low compression ratio (7–11:1)

Objective 6

Complete statements concerning strokes on a four-stroke diesel engine by circling the correct answers.

a. **First stroke: Intake**

- The intake valve **(opens, closes)**.
- Just after the piston reaches TDC, the exhaust valve **(opens, closes)** completely.
- Piston moves **(up, down)** pulling fresh air into the cylinder.

b. **Second stroke: Compression**

- Just after the piston reaches BDC, the intake valve **(opens, closes)** completely.
- Piston moves up, from BDC to TDC, compressing the air charge.
- Just before the piston reaches TDC, **(fuel injection, cooling)** begins.

c. **Third stroke: Power**

- Injected fuel mixes with the superheated air and immediately begins to **(burn, compress)**.
- The rapidly-expanding gases force the piston **(up, down)**.
- Just before the piston reaches BDC, the exhaust valve starts to **(open, close)**.

d. **Fourth stroke: Exhaust**

- The piston moves up, pushing out the spent gases through the **(intake, exhaust)** valve.
- Just before the piston reaches TDC, the intake valve begins to open.

Objective 7

Distinguish between the strokes on a two-stroke diesel engine by placing a "U" next to the upstroke description and a "D" next to the downstroke description.

_____ a. Intake/Compression

_____ b. Power/Exhaust

Objective 8

Distinguish between operating characteristics of two-stroke and four-stroke diesel engines by placing a "2" next to the statements that describe a two-stroke cycle and a "4" next to the statements that describe the four-stroke cycle.

_____ a. Does not typically use an engine-driven blower to charge the cylinder

_____ b. Creates greater engine heat load since the engine fires twice as often

_____ c. Has smoother operation since power strokes occur at shorter intervals

_____ d. Produces a power stroke every two crankshaft revolutions

_____ e. Is more fuel-efficient due to improved valve timing and more effective scavenging of exhaust gases

_____ f. Produces a power stroke every crankshaft revolution

***Permission to duplicate this test is granted.**

Answers to Written Test

Objective 1

a. 27
b. 22
c. 12
d. 30
e. 2
f. 7
g. 18
h. 23
i. 4
j. 25
k. 1
l. 19
m. 13
n. 11
o. 28
p. 16
q. 26
r. 21
s. 14
t. 29

Objective 2

a. 6
b. 7
c. 4
d. 8
e. 2
f. 1
g. 3

Objective 3

Figure 1
a. Water pump
b. Camshaft
c. Push tube
d. Valve rocker (rocker arm)
e. Cylinder block
f. Cylinder head
g. Starter
h. Oil pan
i. Exhaust valve
j. Piston
k. Connecting rod
l. Crankshaft gear

Figure 2
m. Camshaft
n. Intake and exhaust valve assemblies
o. Cam rocker assembly
p. Camshaft gear
q. Water pump
r. Crankshaft
s. Connecting rod
t. Cylinder liner
u. Oil filters
v. Turbocharger
w. Exhaust manifold
x. Cylinder head

Answers to Written Test

Objective 4

a. 2
b. 6
c. 10
d. 4
e. 16
f. 13
g. 1
h. 15
i. 14
j. 3
k. 8
l. 19
m. 9
n. 12
o. 7
p. 11
q. 18

Objective 5

a. D
b. D
c. G
d. D
e. D
f. G
g. G
h. D
i. G

Objective 6

a.
  - Opens
  - Closes
  - Down

b.
  - Closes
  - Fuel injection

c.
  - Burn
  - Down
  - Open

d.
  - Exhaust

Objective 7

a. U
b. D

Objective 8

a. 4
b. 2
c. 2
d. 4
e. 4
f. 2

Prerequisites:
None

Learning Activities Sheet

Student Name ______________________________

Place a checkmark in the appropriate box as you complete each of the steps below.

☐ 1. **Take** Pretest provided by instructor. After test has been evaluated, follow instructor's recommendations.

☐ 2. **Read** Objective Sheet.

☐ 3. **Study** Information Sheet, Objectives 1 through 7.

☐ 4. **Do** Assignment Sheet 1, "Identify Companion Cylinders."

☐ 5. **Stop** Have instructor evaluate the completed assignment sheet and if the evaluation is satisfactory, continue to step 6. If the evaluation is not satisfactory, repeat steps 3, 4, and 5.

☐ 6. **Study** Information Sheet, Objective 8.

☐ 7. **Do** Assignment Sheet 2, "Locate and Record Engine Specifications."

☐ 8. **Stop** Have instructor evaluate the completed assignment sheet and if the evaluation is satisfactory, continue to step 9. If the evaluation is not satisfactory, repeat steps 6, 7, and 8.

☐ 9. **Research** Online resources regarding diesel engine technology. Visit www.detroitdiesel.com as one of your sources.

☐ 10. **Do** Assignment Sheet 3, "Identify Valve and Piston Position During Each Stroke."

☐ 11. **Stop** Have instructor evaluate the completed assignment sheet and if the evaluation is satisfactory, continue to step 12. If the evaluation is not satisfactory, repeat steps 10 and 11.

Learning Activities Sheet

☐ 12. **Observe** Demonstration of procedures to be used in completing Job Sheet 1.

☐ 13. **Do** Job Sheet 1, "Locate TDC for #1 Piston."

☐ 14. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 15. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 1 and repeat steps 12, 13, and 14.

☐ 15. **Observe** Demonstration of procedures to be used in completing Job Sheet 2.

☐ 16. **Do** Job Sheet 2, "Measure Bore and Stroke and Compute Engine Displacement."

☐ 17. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 18. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 2 and repeat steps 15, 16, and 17.

☐ 18. **Check** With instructor for any additional assignments to be completed.

☐ 19. **Do** Additional assignments listed below.

____

____

____

☐ 20. **Take** Posttest provided by instructor. After test has been evaluated, follow instructor's recommendations.

☐ 21. **Stop** Have instructor evaluate your unit performance. If the evaluation is satisfactory, proceed to next learning activities sheet. If evaluation is not satisfactory, ask instructor for further instructions.

***Permission to duplicate this form is granted.**

Teacher Supplement 1—Internet Resources

Increasingly, today's diesel shops are becoming more and more technologically advanced, and there are many reasons why today's electrical/electronic technicians need to be computer savvy. Computers can control almost every aspect of vehicle operations, diagnostic equipment must be designed to interface with that equipment, and technicians must be trained to operate and program both vehicle and diagnostic computers. The Internet can provide numerous resources a technician can access to obtain specifications, find parts, and solve problems by talking to experts.

Engine, Tractor, and Parts and Equipment Manufacturers

The manufacturers listed below provide a multitude of information and services on their websites. Some of these sites contain service bulletins, on-line service manuals, specification sheets, application and installation manuals, diagnostic software, parts information, and question and answer forums.

- Freightliner Trucks – www.freightlinertrucks.com
- Detroit Diesel – www.detroitdiesel.com
- Cummins – www.cummins.com
- Caterpillar – www.caterpillar.com
- International – www.navistarinternational.com
- Mack Trucks – www.macktrucks.com
- Kenworth – www.kenworth.com
- Peterbilt – www.peterbilt.com
- Volvo – www.volvotrucks.com
- John Deere – www.johndeere.com
- Delco-Remy – www.delcoremy.com
- Bendix – www.bendix.com
- Battery Council International—www.batterycouncil.org
- AC Delco—www.acdelco.com
- Exide Batteries—www.exideworld.com
- Interstate Batteries—www.interstatebatteries.com

- Jake Brakes – www.jakebrake.com
- Ambac International (formerly American Bosch) – www.ambac.net
- Stanadyne (fuel system components, injectors, nozzles) – www.standadyne.com
- Bosch – www.boschusa.com
- Telma (driveline retarder systems) – www. telma.com

Other

These websites provide access to certification requirements, trucking industry news, maintenance procedures, and other related links

- National Automotive Technicians Education Foundation (NATEF) – www.natef.org

  Contains information pertaining to medium/heavy-duty truck technician certification.

- National Institute of Automotive Service Excellence (ASE) – www.asecert.org

  Contains information pertaining to medium/heavy-duty truck technician certification.

- American Trucking Association – www.truckline.com

  The American Trucking Association is the national trade association of the trucking industry and home to The Maintenance Council (TMC). Here, you can access TMC's recommended procedures.

- Truck Net – www.truck.net

  This site provides links to various areas in the industry such as education, computer hardware and software, magazines, news, manufacturers, and round table discussions.

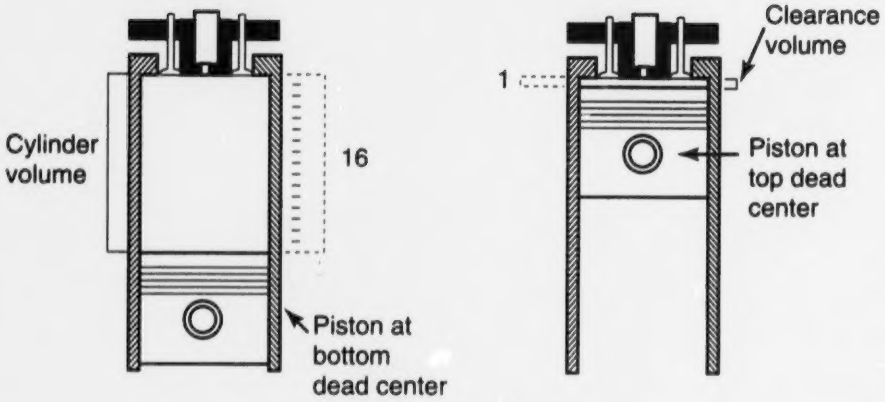
- U.S. Department of Transportation – www.dot.gov

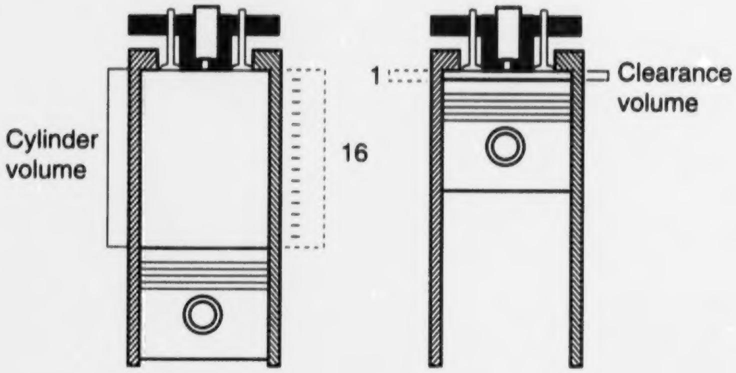
  Links to Department of Transportation, Federal Highway Administration, and Federal Highway Traffic Safety Administration standards and regulations.

- Environmental Protection Agency – www.epa.gov

  Provides information concerning government regulations on emissions

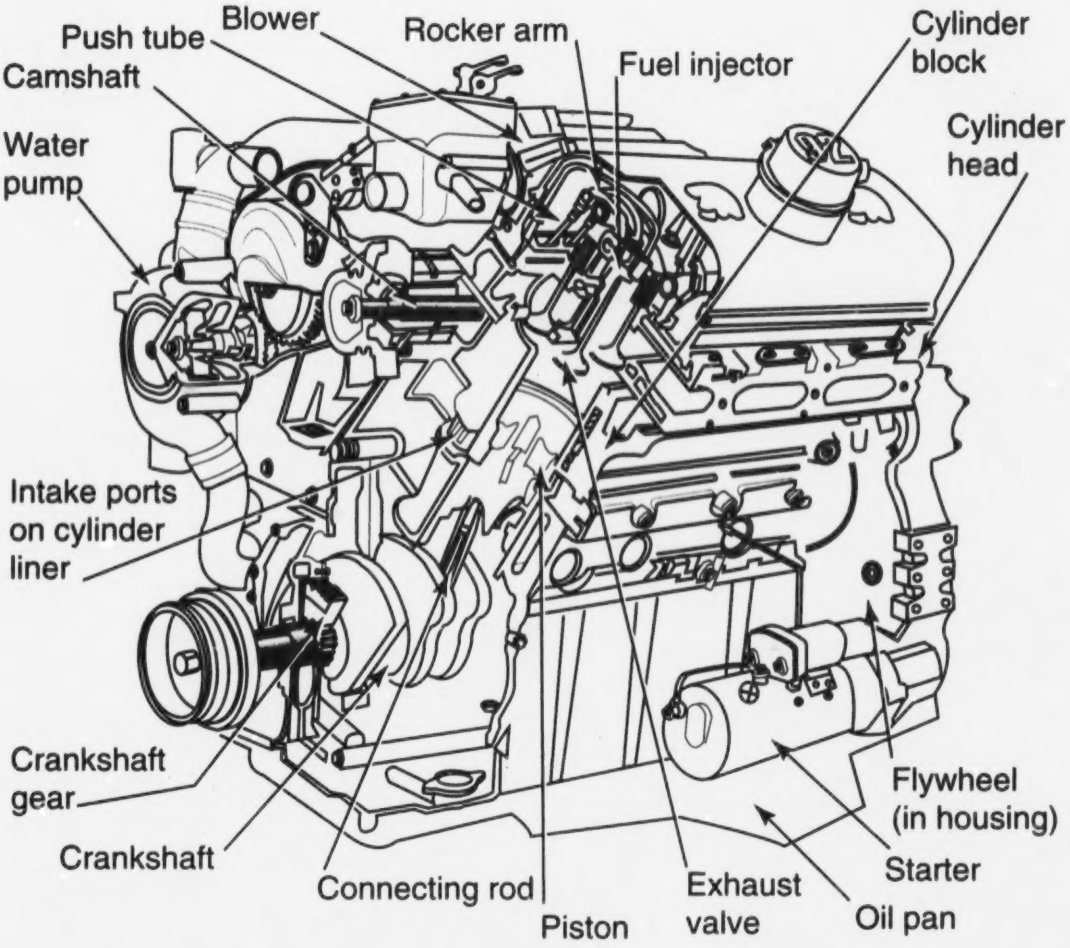
Compression Ratio


Cylinder volume
16
Piston at bottom dead center
1
Clearance volume
Piston at top dead center


Cylinder volume
16
1
Clearance volume

Compression Ratio = 16:1

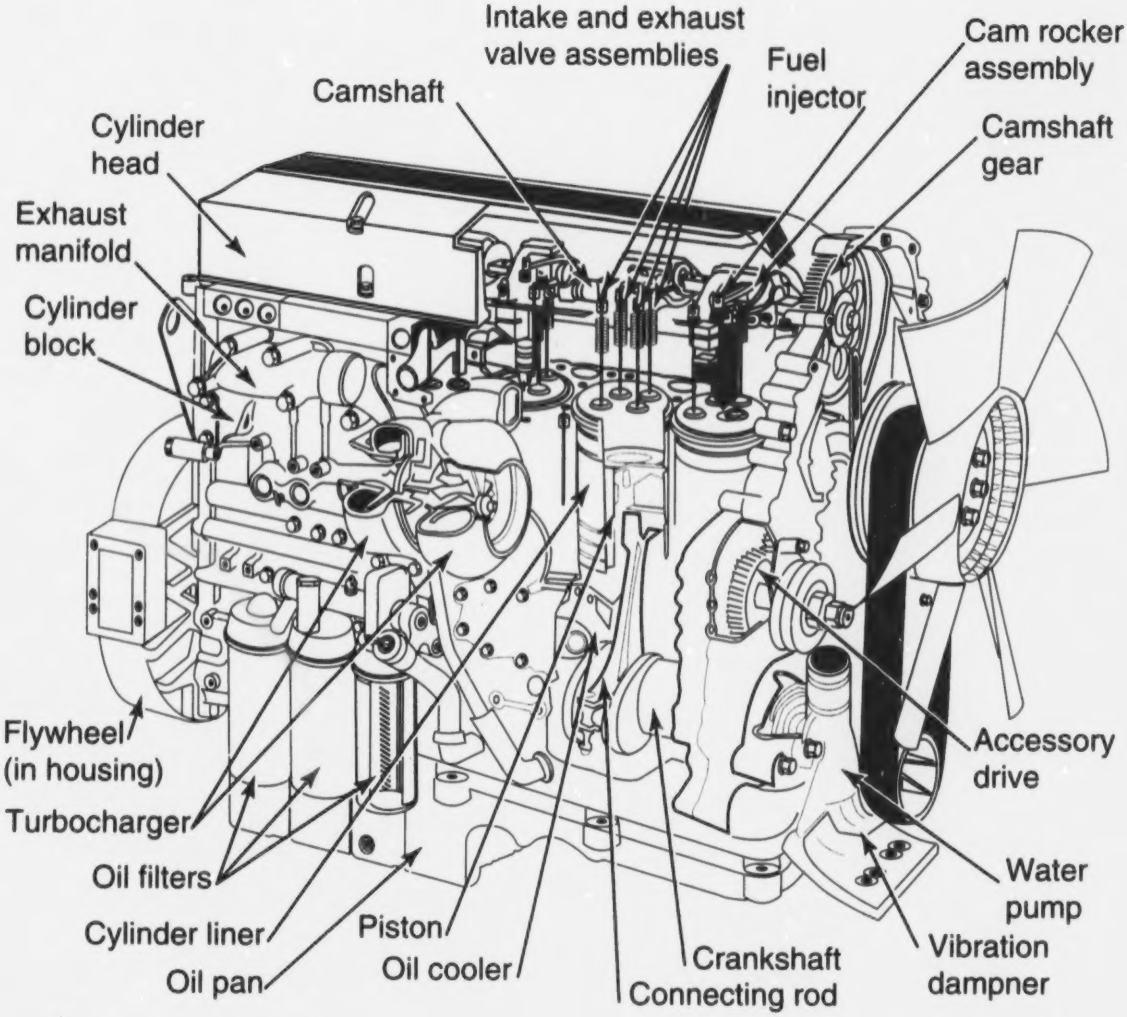
Two-Stroke Diesel Engine Components


Push tube
Blower
Rocker arm
Cylinder block
Camshaft
Fuel injector
Water pump
Cylinder head
Intake ports on cylinder liner
Crankshaft gear
Crankshaft
Connecting rod
Piston
Exhaust valve
Oil pan
Starter
Flywheel (in housing)

Courtesy of Detroit Diesel Corporation

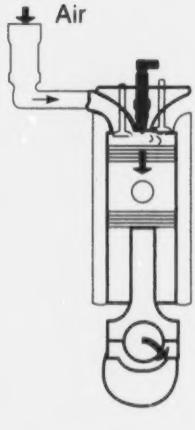
TM 2

Four-Stroke Diesel Engine Components


Intake and exhaust valve assemblies
Fuel injector
Cam rocker assembly
Camshaft
Cylinder head
Camshaft gear
Exhaust manifold
Cylinder block
Flywheel (in housing)
Turbocharger
Oil filters
Cylinder liner
Oil pan
Piston
Oil cooler
Connecting rod
Crankshaft
Accessory drive
Water pump
Vibration dampner

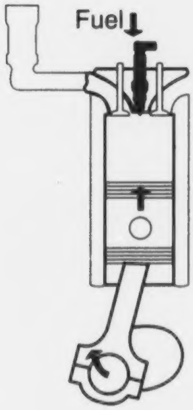
Courtesy of Detroit Diesel Corporation

Four-Stroke Cycle



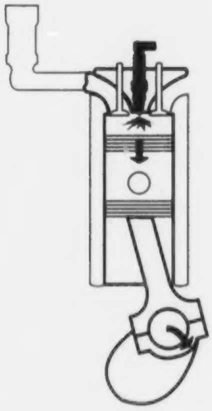
Intake stroke

Intake valve opens. Exhaust valve closes. Piston moves down, pulling fresh air into cylinder.



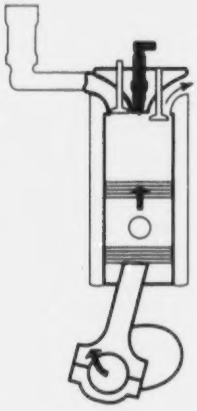
Compression stroke

Intake valve closes. Piston moves up, compressing the air charge. Fuel injection begins.



Power stroke

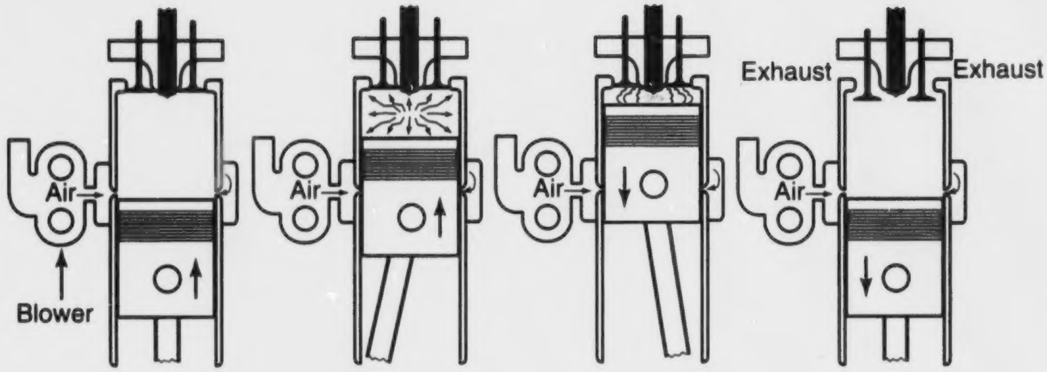
Injected fuel mixes with superheated air and begins to burn. Rapidly-expanding gases force piston down. Exhaust valve starts to open.



Exhaust stroke

Piston moves up, pushing spent gases out exhaust valve. Intake valve begins to open.

Two-Stroke Cycle



Intake **Compression** **Power** **Exhaust**

1. Upstroke

Intake: As piston moves up the cylinder, exhaust valves close and air fills cylinder.

Compression: Rising piston covers intake ports, cylinder filling stops, and piston compresses air charge. Fuel injection begins.

2. Downstroke

Power: Injected fuel mixes with superheated air and begins to burn. Rapidly-expanding gases force piston down.

Exhaust: Exhaust valves open and spent exhaust gases leave cylinder. Piston continues down, uncovering intake ports. Compressed fresh air forces remaining exhaust gases out the exhaust valves.

Unit 2-A Disassembly Procedures and Analysis

Unit Contents

Teacher Components

Teacher Page

Suggested Activities 2A-3

Answers to Assignment Sheets 2A-11

Written Test 2A-13

Answers to Written Test 2A-21

Learning Activities Sheet 2A-25

Transparency Master

1—Normal Wear Components 2A-29

Student Components

Student Page

Objective Sheet 2A-3

Information Sheet 2A-5

Assignment Sheets

1—Determine Required Tools for Various Tasks 2A-19
2—Evaluate Worn Engine Components 2A-21
3—Determine Possible Causes of Engine Component Failures . . . 2A-25

Job Sheets

1—Steam Clean an Engine 2A-27
2—Remove Engine Accessories and External Lines 2A-31
3—Remove the Engine and Mount on an Engine Stand 2A-35
4—Engine Disassembly: Remove Cylinder Head 2A-39
5—Engine Disassembly: Remove Gear Train and Camshaft 2A-43
6—Engine Disassembly: Remove Pistons and Connecting Rods . . 2A-47
7—Engine Disassembly: Remove Cylinder Liners 2A-51
8—Engine Disassembly: Remove Crankshaft 2A-55

Suggested Activities

Instructional Plan

Preparation

- Read the unit carefully and plan for instruction.
- Review "Teaching Suggestions." Plan for classroom activities.
- Plan your presentation to take advantage of student learning styles and to accommodate special-needs students.
- Prepare classroom. Put up posters and charts and display articles and other references related to this unit.
- Obtain films, videotapes, and other resources to supplement instruction of this unit. See "Resources Used in Developing This Unit" and "Suggested Supplemental Resources" for more information.
- For self-paced instruction, review Learning Activities Sheet. Modify as appropriate to include additional activities and/or resources available in your classroom. Make one copy for each student.
- Make a transparency from the transparency master included in this unit. This appears in the teacher edition only.

Delivery and Application

Unit Introduction (self-paced instruction)

- Provide student with Learning Activities Sheet and unit of instruction.
- Review unit contents with student.
- Have the student complete the steps in the learning activities sheet.

Unit Introduction (group instruction)

- Provide students with unit of instruction.
- Discuss unit and specific objectives.
- Discuss the information sheet. Implement teaching plan to localize, supplement, and personalize the unit. Reinforce basic academic and workplace skills when applicable.
- Discuss the assignment sheets. Review with students the criteria for evaluation of these activities.

Suggested Activities

- Discuss and demonstrate the job sheets. Make sure all required tools, equipment, and materials are available. Review with students the criteria for evaluation of these activities and the rating scale that will be used to indicate job performance.

Teaching Suggestions

- Make a display of all special engine tools covered in Objective 2 with identifying labels so students can practice identifying them. You may wish to then remove the labels and give students a hands-on practical test to identify the tools on display. This test/quiz may be conducted individually or as a class or team activity.
- A similar activity would be useful for the precision measuring instruments used for engine measurement and analysis covered in Objective 3. Review the instruments that students may already be familiar with and then discuss the new instruments that are only used for engine work. Give students practice time for hands-on use of these instruments. Also discuss the precautions necessary when handling precision instruments. Emphasize that many are delicate and expensive.
- Discuss the safety hazards associated with working on heavy diesel engines and their components as listed in Objective 4. Personalize the information by relating any experiences you have had with accidents or mishaps that occurred when lifting or moving heavy engines. Demonstrate the use of lifting devices.
- You may want to conduct individual safety checks where each student demonstrates his/her ability to lift and move heavy equipment using the proper tools and techniques. These safety demonstrations should be recorded as appropriate for your educational setting and placed in each student's permanent file.
- On an actual vehicle or other piece of diesel equipment, have students label or tag all accessory components and lines that must be pulled before the engine is removed as listed in Objective 6.
- Show examples of the tools, equipment, and chemicals that may be used to clean engine components. Make sure students understand which ones can be used on aluminum and other soft metals and which ones can't.
- Use damaged components to illustrate the difference between wear and failure. These components could also be used to show the types of wear and types of failure.
- Conduct a field trip to a local repair facility to observe failure analysis investigations being performed. If possible, have the owner, supervisor, or master technician discuss the most common problems that cause failures and what can be done to prevent failures.

- Provide new examples of damaged components for students to use in Assignment Sheets 2 and 3. Refer to the Assignment Sheets for a list of the specific components required.

Evaluation

- Make copies of the written test. Add or modify test items as needed. The written test serves as both a pretest and posttest to assist in measuring each student's competency gains.
- Give and evaluate pretest. Modify lesson plan to include additional instruction for those areas where students were deficient.
- Evaluate the assignment sheets. Rate the student using the criteria listed on each assignment sheet. See Answers to Assignment Sheets for correct answers where applicable. If the student's performance is unacceptable, have the student review the appropriate materials and complete the assignment again.
- Evaluate the job sheets. When the student is ready to perform a specific task, obtain a copy of the job sheet which may be found in the student edition. Then observe the student performing the procedure.

  Process evaluation—Place a mark in the box to the left of each designated checkpoint if the student has satisfactorily completed the process step(s) for each checkpoint area. If the student is unable to complete the procedure correctly, have the student review the materials and try again.

  Product evaluation—Once the student has satisfactorily completed the procedure, rate the student product (outcome) using the criteria that are provided as part of the job sheet. If the student's product is unacceptable, have the student review the materials and submit another product for evaluation.

  Two sample performance evaluation keys have been provided below. Many other keys are available. Select one rating (grading scale) that best fits your program needs.

Sample A

4—**Skilled**—Can perform job with no additional training.
3—**Moderately skilled**—Has performed job during training program; limited additional training may be required.
2—**Limited skill**—Has performed job during training program; additional training is required to develop skill.
1—**Unskilled**—Is familiar with process, but is unable to perform job.
0—**No exposure**—No information or practice provided during training program.

Suggested Activities

Sample B

Yes—Can perform job with no additional training.
No—Is unable to perform job satisfactorily.

- Give and evaluate the posttest.
- Meet individually with students to evaluate their progress through this unit of instruction and indicate to them possible areas of improvement.
- Reteach and retest as required.

Resources Used in Developing This Unit

Print Media

- *Applied Failure Analysis.* Peoria, IL Caterpillar, Inc.
- Clark, Elton, et al. *Diesel Fundamentals.* Stillwater, OK: Mid-America Vocational Curriculum Consortium, Inc., 1988.
- Dagel, John F. *Diesel Engine and Fuel System Repair*, 4th ed. Upper Saddle River, NJ: Prentice Hall, 1994.
- Espenschied, Roland F. *Diesel Engines.* Athens, GA: American Association for Vocational Instructional Materials, 1990.
- *Fundamentals of Service: Engines*, 7th ed. Moline, IL: Deere and Company, 1991.

Suggested Supplemental Resources

Print Media

- *Engine Troubleshooting Guide* (20SE 0078)
- Retention cards (10/pkg)
  - — *Engine Vibration Complaints* (25ST 0387)
  - — *Failure Analysis of Cylinder Head* (25ST 0395)
  - — *Fundamentals of Failure Analysis* (25ST 0399)
  - — *Failure Analysis Cylinder Components* (25ST 0403)
  - — *Failure Analysis Crankshaft* (25ST 0403)

The above are available from your local Detroit Diesel distributor/dealer or order from the following:

Robot Literature Distribution
12085 Dixie
Redford, MI 48239
Phone: 313-255-9300 or Fax: 313-255-7680

- *Failure Analysis–Bearings*. (985573). Available as booklet or slide set.
- *Failure Analysis–Pistons and Liners*. (985579). Available as booklet or slide set.
- *Failure Analysis–Cylinder Head and Valve Train*. (9985586). Available as booklet or slide set.
- *Turbocharger Failure Analysis*. (3387125). Available as booklet, slide set, or audio tape.
- *Oil Consumption Analysis*. (3387148). Available as booklet, slide set, or audio tape.
- *Sealing Failures–Causes and Cures*. (3387169). Available as booklet, slide set, or audio tape.
- *Failure Analysis Introduction–Metal Structure*. (3387200). Available as booklet, slide set, or audio tape.
- *Failure Analysis–Steel Parts Fractures*. (3387210). Available as booklet.

The above are available from your local Cummins Engine Company dealer/distributor or call:

Cummins Engine Company Customer Relations
800-345-5654 or 502-453-8549 or for more information call 1-800-DIESELS

- *Failure Analysis of Pistons, Rings, Liners, and Sleeves Service Manual*. (21-1)
- *E6-4VH Piston Failure Analysis Service Manual*. (21-1A)
- *Turbocharger Failure Analysis Service Manual*. (21-1.1)
- *Engine Bearing Failure Analysis Service Manual*. (21-1.2)
- *Gear Failure Analysis Service Manual*. (21-1.3)

The above are available from:

Mack Trucks, Inc.
2100 Mack Boulevard
P.O. Box M
Allentown, PA 18195-5000
610-439-3011

Suggested Activities

- Set of CAT Applied Failure Analysis Reference books (SEBV0568) (1991). Also available individually. Set includes:

  — *Engine Bearing Failure Analysis*

  — *Threaded Fastener Failure Analysis*

  — *Connecting Rod Failure Analysis*

  — *Principles of Visual Examination*

  — *Crankshaft Failure Analysis*

  — *Principles of Metallurgy*

  — *Turbocharger Failure Analysis*

  — *Engine Valve Failure Analysis*

  — *Principles of Fractures*

  — *Piston, Ring, and Liner Failure Analysis*

  — *Principles of Wear*

  — *Gear Failure Analysis*

  — *Anti-friction Bearing Failure Analysis*

  — *Hydraulic Pump and Motor Failure Analysis*

  — *Shaft Failure Analysis*

  — *Weld Failure Analysis*

  — *Principles of Lubrication*

  Set of reference books is available from your local CAT dealer or write the following for more information:

  Caterpillar Service Training
  600 W. Washington St., Bldg. JJ
  East Peoria, IL 61630

Electronic Media

- *Chains/Slings/Hoists* (9017A), 12-minute videotape—Discusses slings, lifting, angles, safety procedures, inspection procedures, and more. Available from:

  MAVCC at www.mavcc.org, or call 800.654.3988

- *Diesel Engine Teardown* video (MER-5212-VW). Details the steps needed to disassemble, inspect, and measure the parts of a diesel engine. ©1993. Available from:

  NIMCO
  102 Hwy. 81 North
  P.O. Box 9
  Calhoun, KY 42327-0009
  Phone: 800-962-6662 or Fax: 502-273-5844
  http://www.nimcoinc.com

- *FOS Identification of Parts Failures* set of 224 slides. Available from:

  John Deere Publishing
  5440 Corporate Park Drive
  Davenport, IA 52807
  1-800-522-7448
  http://www.deere.com

- *Diesel Engine Overhaul* (VH1-67PT), 58-minute videotape—Shows a step-by-step teardown, inspection, and assembly for out-of-frame block repairs to a four-stroke cycle Cummins engine. Three parts.

- *Detroit Diesel Overhaul* (VH1-87PT), 58-minute videotape—Shows the procedures and tips to major block rebuilding of the two-stroke cycle Detroit Diesel engine. Three parts.

- *Dirt–Engine Enemy #1* (VH1-90PT), 10-minute videotape—Shows abrasive wear from dirt on pistons, rings, cylinders, bearings, and other components.

- *Engine Diagnosis and the Cooling System* (VH1-101PT), 11-minute videotape—Discusses the steps in engine diagnosis and common cooling system problems and failures.

  The above are available from:

  Dana Corporation
  Publication Services
  P.O. Box 453
  Toledo, OH 43692-0453
  Phone: 419-535-4285 or Fax: 419-535-4396

Answers to Assignment Sheets

Assignment Sheet 1

Determine Required Tools for Various Tasks

1. Lifting device
2. Liner puller
3. Crank lifting tool and engine stand
4. Valve spring compressor
5. Bore gauge
6. Outside micrometer

Assignment Sheet 2

Evaluate Worn Engine Components

Answers will depend on condition of actual engine components provided by instructor

Assignment Sheet 3

Determine Possible Causes of Engine Component Failures

Answers will depend on condition of actual engine components provided by instructor

Written Test

Name ______________________________

Date ______________________ Score __________

Objective 1

Match terms related to disassembly procedures and analysis with their definitions. Definitions continue on the next page.

1. Beach marks
2. Carbon deposits (black)
3. Cavitation
4. Cavitation erosion
5. Clearance
6. Contaminate
7. Corrode
8. Defect
9. Failure
10. Fatigue
11. Foreign material
12. Indicator
13. Pitted
14. Polished
15. Ratchet marks
16. Root cause
17. Scored
18. Scuffed
19. Seize
20. Viscosity
21. Wear

_____ a. Specific condition that started the problem

_____ b. To make unfit for use by contact with foreign material

_____ c. Undesirable removal of material from the surface of a part

_____ d. Radial stress lines spreading outward from a fatigue crack

_____ e. Gradual erosion and pitting of parts exposed to bursting cavitation bubbles

_____ f. Inability to perform the desired function; usually occurs prematurely or unexpectedly

_____ g. Formation of bubbles in a fluid that occurs when the fluid is subjected to low pressures

_____ h. Indentations or holes in the surface of an object

_____ i. Tendency of a material to break under repeated stress

_____ j. Surface wear caused by friction between parts

_____ k. To weaken or destroy gradually by chemical means

_____ l. Marked with lines or scratches

_____ m. Any extraneous material not intended to be present

_____ n. Measure of a fluid's resistance to flow

_____ o. By-products of combustion deposited on piston domes, rings, ring grooves, cylinder head(s), valves, and injector tips

_____ p. Symptom that helps identify product, operation, or maintenance problem

_____ q. To bond to a moving part through excessive pressure, temperature, or friction

_____ r. Tiny fractures developing between individual cracks

Objective 2

Match special engine tools with their functions. Functions continue on the next page.

1. Camshaft bushing remover/installer
2. Engine pre-oiler
3. Engine stand
4. Fuel sight gauge
5. Gear puller
6. Harmonic balancer puller
7. Injector removal tools
8. Lift T-handles
9. Liner installer
10. Liner puller
11. Ring compressor
12. Ring expander
13. Rod bolt protectors
14. Valve spring compressor
15. Valve spring tester

_____ a. Remove threaded, pencil-type, and "Top Stop" injectors

_____ b. Indicates valve spring operating tension

_____ c. Removes and replaces camshaft bushings in all gas and diesel engines

_____ d. Presses the cylinder liner/cylinder pack into the cylinder block

_____ e. Supports the engine's weight, allowing safe access to all engine components

_____ f. Removes and installs piston rings without breakage

_____ g. Attaches to inlet side of fuel pump to visually identify air leaks in the suction side of the fuel delivery system

_____ h. Compresses the valve spring, allowing removal or installation of valve spring keepers

_____ i. Pressurizes the lubricating system prior to start-up to ensure positive lubrication to all friction surfaces

_____ j. Guide the connecting rod bolts over the crankshaft rod journal while protecting the machined surface of the journal

_____ k. Replace rocker arms and provide lifting points for cylinder head removal

_____ l. Removes the harmonic balancer without damaging the inertia ring

_____ m. Aids installation of piston and ring assembly into the cylinder liner/cylinder bore

_____ n. Uses torque or hydraulic pressure to remove gears in place

Objective 3

Match precision measuring instruments with their functions. Functions continue on the next page.

1. Ball and hole gauge
2. Depth gauge
3. Dial bore gauge
4. Dial test indicator
5. Diesel compression gauge
6. Direct contact pyrometer
7. Feeler gauge
8. Infrared pyrometer
9. Inside micrometer
10. Magnahelic gauge
11. Magnetic gauge base
12. Manometer
13. Micrometer
14. Outside calipers
15. Precision straight-edge
16. Protrusion gauge
17. Radius gauge set

_____ a. Measures cylinder liner lip protrusion above the cylinder block surface

_____ b. Measures clearance between two mating parts

_____ c. Measures distance between two surfaces

_____ d. Measures surface temperature at point of contact

_____ e. Mounts and positions dial test indicators to flat or round metal surfaces

_____ f. Provides an accurate reference for measuring warpage of machined surfaces

_____ g. Measures small bore diameters, such as valve guides

_____ h. Measures inner diameter of a cylinder, tube, or journal

_____ i. Measures back-and-forth movement of a component

_____ j. Measures outer diameter and thickness; measurement is read on a graduated scale

_____ k. Measures cylinder diameter to determine wear, out-of-round, and taper

_____ l. Measures surface temperature of an object when pointed at that object; does not require physical contact to give an accurate reading

_____ m. Measures the pressure of gases and vapors

_____ n. Measures maximum cylinder pressure; gives indication of ring and valve seat wear

_____ o. Highly accurate gauge that measures small changes in vacuum or pressure

Objective 4

Complete statements concerning safety guidelines to follow during engine removal and disassembly by filling in the blanks with the correct answers.

a. Use hoist or chain for lifting any components over ____________________ pounds.

b. Use guide studs/dowels to help ____________________ parts.

c. Always keep hands and fingers away from ____________________ parts.

d. Wear all ____________________ ____________________ ____________________, as required, including safety glasses and gloves.

e. Follow all ____________________ ____________________ ____________________, and remember that "safety always comes first." Eyes and fingers are hard to replace!

Objective 5

Discuss two good housekeeping practices and procedures.

a. ____

____

b. ____

____

____

Objective 6

Select from a list accessory components and lines that must be pulled before the engine is removed by placing an "X" in the appropriate blanks.

_____ a. Battery

_____ b. Alternator leads

_____ c. Radiator hose

_____ d. Spark plugs

_____ e. Fan/fan clutch

_____ f. Air conditioning compressor

_____ g. Fuel supply lines

_____ h. Transmission

Objective 7

Match methods for cleaning engine components with their descriptions.

1. Abrasive disc
2. Bead blasting/crushed media blasting
3. High pressure hot water
4. Solvent and bristle brush
5. Wire wheel

_____ a. Larger parts are easily cleaned. Safe for all metals.

_____ b. For cleaning individual hand-held components; ideal for cleaning aluminum

_____ c. Not suitable for aluminum or soft metal; injury hazard from flying wire particles

_____ d. For initial grease/grime removal from engine, transmission, and frame; avoid spraying electrical components

_____ e. Quickly removes gasket material

Objective 8

Discuss two engine components that require measurement and analysis. Then describe what specifically needs to be measured about these components.

Example: Connecting rod—Wrist pin bushing inside diameter

a. ____

____

b. ____

____

Written Test

Objective 9

Match types of materials used on engine components with their applications.

1. Aluminum alloys
2. Cast iron
3. Steel
4. Synthetic materials, including ceramics and plastics

_____ a. Used on pistons and many new parts to reduce engine weight without sacrificing strength

_____ b. Used on crankshafts, camshafts, connecting rods, valves, and gears

_____ c. Used on cylinder blocks, cylinder heads, rocker housings, and some gears

_____ d. Used on many replaceable parts such as lines, fittings, seals, and electronic components

Objective 10

Distinguish between types of analyses by placing an "F" next to failure analysis descriptions and a "W" next to wear analysis descriptions.

_____ a. Parts are inspected to determine what conditions led to the component failure.

_____ b. End result is an engine suitable for future service.

_____ c. Primary concern is reconditioning the engine for further service.

_____ d. Determines conditions leading to root cause of unexpected component failure

_____ e. Parts are inspected to determine what reconditioning procedures are necessary.

_____ f. Primary concern is prevention of future component failure.

_____ g. Determines conditions leading to root cause of component wear

_____ h. End result involves future change in either manufacturing, service, or operation of the engine.

Objective 11

Arrange in order the following steps of failure analysis by placing the correct sequence numbers (1-8) in the appropriate blanks.

_____ a. Follow-up with the customer.

_____ b. Observe and record the facts.

_____ c. Identify the most probable root cause.

_____ d. Think logically with the facts.

_____ e. Communicate your findings with the responsible party.

_____ f. Organize your fact-gathering.

_____ g. Make repairs as directed.

_____ h. State the problem clearly and concisely.

Objective 12

Distinguish between normal and abnormal wear by placing an "N" next to descriptions of normal wear and an "A" next to descriptions of abnormal wear.

_____ a. Valves, guides, and seats

_____ b. Crankshafts and camshafts

_____ c. Main and rod bearings

_____ d. Cylinder blocks

_____ e. Cylinder liners

_____ f. Piston rings

_____ g. Pistons and connecting rods

Objective 13

Match common types of mechanical wear with their characteristics.

1. Abrasive wear
2. Adhesive wear
3. Cavitation erosion
4. Corrosive wear
5. Erosive wear
6. Fretting wear

_____ a. Occurs when small hard particles, carried by fast-moving fluids, strike metal surfaces at high speeds

_____ b. Consists of localized bonding between contacting surfaces that leads to material transfer from one surface to the other or loss of material from either surface

_____ c. Occurs when tight fitting (shift or press fit) parts are allowed to move slightly against each other such as by vibration

_____ d. Occurs when metal surfaces are exposed to an electrolyte, dissimilar metals (for example, aluminum in contact with steel), or high temperatures

_____ e. Occurs when hard particles such as dirt or debris get trapped in the lubricating film between moving parts

_____ f. Occurs when vapor bubbles in a fluid strike a metal surface

Written Test

Objective 14

Discuss two root causes of the following system failures.

a. Fuel system failure

- ______________________________
- ______________________________

b. Cooling system failure

- ______________________________
- ______________________________

***Permission to duplicate this test is granted.**

Answers to Written Test

Objective 1

a.	16	f.	9	k.	7	p.	12
b.	6	g.	3	l.	17	q.	19
c.	21	h.	13	m.	11	r.	15
d.	1	i.	10	n.	20		
e.	4	j.	18	o.	2		

Objective 2

a.	7	f.	12	k.	8
b.	15	g.	4	l.	6
c.	1	h.	14	m.	11
d.	9	i.	2	n.	5
e.	3	j.	13		

Objective 3

a.	16	f.	15	k.	3
b.	7	g.	1	l.	8
c.	2	h.	9	m.	12
d.	6	i.	4	n.	5
e.	11	j.	13	o.	10

Objective 4

a. 45
b. Center (match)
c. Mating
d. Personal protective equipment
e. Shop safety rules

Objective 5

Any two of the following:

a. Keep attaching hardware with their components. You may use:
  - Plastic bags labeled or wire-tied to the part
  - Coffee cans labled with their contents

b. Keep workbench surface clean. It should be:
  - Free of dirt and grease
  - Clear of paper towels and other trash
  - Clear of open containers of solvent, lubricants, etc.

c. Store parts in groups as subassemblies.
  - Group parts as assemblies
  - Mark parts with paint sticks or tags
  - Mark engine brackets as they are removed

d. Retain old parts to compare with new ones.

e. Put away tools and equipment when not in use.

Objective 6

b, c, e, f, g

Answers to Written Test

Objective 7

a. 4
b. 2
c. 5
d. 3
e. 1

Objective 8

Any two of the following:

a. **Cylinder head**
  - Fire deck flatness
  - Valve stem diameter
  - Valve guide wear
  - Valve condition
  - Seat condition

b. **Crankshaft**
  - End play
  - Main journal diameter
  - Rod journal diameter
  - Fillet
  - Journal surface color

c. **Cylinder block**
  - Liner protrusion/height
  - Liner counter bore
  - Camshaft bearing inside diameter
  - Crankshaft main bearing bore alignment
  - Block-to-head mating face flatness

d. **Piston/liner**
  - Liner/bore inside diameter
  - Piston-to-bore clearance
  - Liner surface
  - Piston crown
  - Piston thrust face

e. **Connecting rod**
  - Wrist pin bushing inside diameter
  - Big-end bore inside diameter

f. **Camshaft/lifters**
  - Lobe condition
  - Journal outside diameter
  - Lifter condition

g. **Flywheel**
  - Clutch surface condition
  - Surface runout
  - Starter ring gear wear

Objective 9

a. 1
b. 3
c. 2
d. 4

Answers to Written Test

Objective 10

a. F
b. W
c. W
d. F
e. W
f. F
g. W
h. F

Objective 11

a. 8
b. 3
c. 5
d. 4
e. 6
f. 2
g. 7
h. 1

Objective 12

a. N
b. A
c. N
d. A
e. N
f. N
g. A

Objective 13

a. 5
b. 2
c. 6
d. 4
e. 1
f. 3

Objective 14

a. **Fuel system failures—Any two of the following:**
- Wrong fuel
  - — Incorrect grade
  - — Incorrect sulfur level
- Contaminated fuel (biological, dirt, or water)
- Incorrect installation for components or lines
- Incorrect timing of fuel injectors

b. **Cooling system failures—Any two of the following:**
- Supplemental coolant additive (SCA) problems
  - — Too little or too much
  - — Incorrect or incompatible type
  - — Deteriorated or low quality
- Coolant problems
  - — Incorrect mix of water, antifreeze, and additives
  - — Contaminated coolant (metal, dirt, oil)
- Faulty cooling system components (thermostat, fan, pump) that cause engine to run too hot or too cool

Prerequisites:
Unit 1-A

Learning Activities Sheet

Student Name ______________________________

Place a checkmark in the appropriate box as you complete each of the steps below.

☐ 1. **Take** Pretest provided by instructor. After test has been evaluated, follow instructor's recommendations.

☐ 2. **Read** Objective Sheet.

☐ 3. **Study** Information Sheet, Objectives 1 through 3.

☐ 4. **Do** Assignment Sheet 1, "Determine Required Tools for Various Tasks."

☐ 5. **Stop** Have instructor evaluate the completed assignment sheet and if the evaluation is satisfactory, continue to step 6. If the evaluation is not satisfactory, repeat steps 3, 4, and 5.

☐ 6. **Study** Information Sheet, Objective 4.

Optional

☐ 7. **View** Videotape entitled *Chains/Slings/Hoists.*

☐ 8. **Study** Information Sheet, Objectives 5, 6, and 7.

☐ 9. **Observe** Demonstration of procedures to be used in completing Job Sheet 1.

☐ 10. **Do** Job Sheet 1, "Steam Clean an Engine."

☐ 11. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 12. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 1 and repeat steps 8 through 11.

☐ 12. **Study** Information Sheet, Objectives 8 and 9.

☐ 13. **Observe** Demonstration of procedures to be used in completing Job Sheet 2.

Learning Activities Sheet

☐ 14. **Do** Job Sheet 2, "Remove Engine Accessories and External Lines."

☐ 15. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 16. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 2 and repeat steps 12 through 15.

☐ 16. **Study** Information Sheet, Objectives 10 through 13.

☐ 17. **Do** Assignment Sheet 2, "Evaluate Worn Engine Components."

☐ 18. **Stop** Have instructor evaluate the completed assignment sheet and if the evaluation is satisfactory, continue to step 19. If the evaluation is not satisfactory, repeat steps 16, 17, and 18.

☐ 19. **Observe** Demonstration of procedures to be used in completing Job Sheet 3.

☐ 20. **Do** Job Sheet 3, "Remove Engine and Mount on an Engine Stand."

☐ 21. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 22. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 3 and repeat steps 19, 20, and 21.

☐ 22. **Study** Information Sheet, Objective 14.

☐ 23. **Do** Assignment Sheet 3, "Determine Possible Causes of Engine Component Failures."

☐ 24. **Stop** Have instructor evaluate the completed assignment sheet and if the evaluation is satisfactory, continue to step 25. If the evaluation is not satisfactory, repeat steps 22, 23, and 24.

☐ 25. **Observe** Demonstration of procedures to be used in completing Job Sheets 4 through 8.

☐ 26. **Do** The following engine disassembly job sheets: **Job Sheet 4**, "Remove Cylinder Head," **Job Sheet 5**, "Remove Gear Train and Camshaft," **Job Sheet 6**, "Remove Pistons and Connecting Rods," **Job Sheet 7**, "Remove Cylinder Liners," **Job Sheet 8**, "Remove Crankshaft."

☐ 27. **Stop** After completing each job sheet, have your instructor evaluate your performance. If the evaluation is satisfactory, continue to the next job sheet. If the evaluation is not satisfactory, study the procedure outlined in that job sheet, and redo the job sheet. After satisfactorily completing Job Sheet 4 through 8, continue to step 28.

☐ 28. **Check** With instructor for any additional assignments to be completed.

☐ 29. **Do** Additional assignments listed below.

____

____

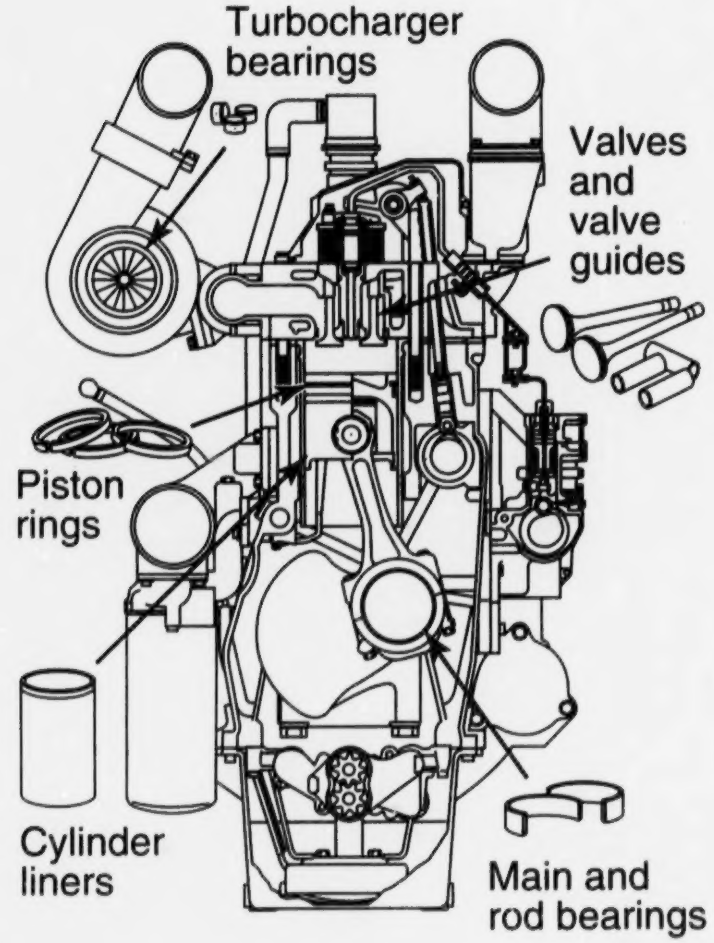
____

☐ 30. **Take** Posttest provided by instructor. After test has been evaluated, follow instructor's recommendations.

☐ 31. **Stop** Have instructor evaluate your unit performance. If the evaluation is satisfactory, proceed to next learning activities sheet. If evaluation is not satisfactory, ask instructor for further instructions.

***Permission to duplicate this form is granted.**

Normal Wear Components


Turbocharger bearings
Valves and valve guides
Piston rings
Cylinder liners
Main and rod bearings

© Caterpillar Inc. Used with permission

Unit Contents

Teacher Components

Teacher Page

Suggested Activities 1B-3
Written Test 1B-9
Answers to Written Test 1B-15
Learning Activities Sheet 1B-17

Transparency Masters

1—Lubrication System Components 1B-19
2—Basic Oil Pump Designs 1B-21
3—Basic Oil Cooler Designs 1B-23

Student Components

Student Page

Objective Sheet 1B-3
Information Sheet 1B-5

Job Sheets

1—Service and Install Oil Pump and Oil Pump Drive Components 1B-15
2—Service and Inspect Lubrication System Screens and Pipes 1B-19
3—Service and Inspect Oil Pressure Regulator Valve and Bypass Valve 1B-23
4—Service and Inspect Oil Cooler and Lines 1B-27

Instructional Plan

Suggested Activities

Preparation

- Read the unit carefully and plan for instruction.
- Review "Teaching Suggestions." Plan for classroom activities.
- Plan your presentation to take advantage of student learning styles and to accommodate special-needs students.
- Prepare classroom. Put up posters and charts and display articles and other references related to this unit.
- Obtain films, videotapes, and other resources to supplement instruction of this unit. See "Resources Used in Developing This Unit" and "Suggested Supplemental Resources" for more information.
- For self-paced instruction, review Learning Activities Sheet. Modify as appropriate to include additional activities and/or resources available in your classroom. Make one copy for each student.
- Make transparencies from the transparency masters included in this unit. These appear in the teacher edition only.

Delivery and Application

Unit Introduction (self-paced instruction)

- Provide student with Learning Activities Sheet and unit of instruction.
- Review unit contents with student.
- Have the student complete the steps in the learning activities sheet.

Unit Introduction (group instruction)

- Provide students with unit of instruction.
- Discuss unit and specific objectives.
- Discuss the information sheet. Implement teaching plan to localize, supplement, and personalize the unit. Reinforce basic academic and workplace skills when applicable.

Suggested Activities

- Discuss and demonstrate the job sheets. Make sure all required tools, equipment, and materials are available. Review with students the criteria for evaluation of these activities and the rating scale that will be used to indicate job performance.

Teaching Suggestions

- Provide examples of assembled diesel engine equipment/vehicles so students can identify the parts of the lubrication system. Provide students with heavyweight paper cards already labeled with the part names and have students tape the correct cards to the correct parts. This should help students see the "big picture."

- Show students individual examples of basic lubrication system components including:

  — Oil filters

  — Oil pumps

  — Oil coolers

  — Pressure regulator and bypass valves

  — Miscellaneous lines, pipes, and screens

- Discuss their designs and operation. Allow students to handle the parts and become familiar with them.

- Have students brainstorm ideas about causes of oil contamination. Sources are listed in the information sheet (Objective 8), but help the students think of how the contamination could have occurred. For example, dirt is the number one source of oil contamination, but how does dirt get in the lubrication system? Where is the real problem?

- Discuss the most common problems that you have encountered with lubrication systems. Also discuss how these problems affected the engine. Describe the inexpensive precautions (new seals, fresh lubricant, new filters, etc.) that could have saved the owner from expensive engine wear/failure problems. Stress the economic benefits of preventive maintenance.

- Show samples of engine and lubrication system parts that show excessive wear. Have students analyze and determine the root cause.

- Show examples of different brands of engine oils, and have students find and explain the API symbol on each.

- Discuss EPA guidelines and your shop practices for disposing of waste oil. Demonstrate the correct procedures and recordkeeping required.

Evaluation

- Make copies of the written test. Add or modify test items as needed. The written test serves as both a pretest and posttest to assist in measuring each student's competency gains.
- Give and evaluate pretest. Modify lesson plan to include additional instruction for those areas where students were deficient.
- Evaluate the job sheets. When the student is ready to perform a specific task, obtain a copy of the job sheet which may be found in the student edition. Then observe the student performing the procedure.

  Process evaluation—Place a mark in the box to the left of each designated checkpoint if the student has satisfactorily completed the process step(s) for each checkpoint area. If the student is unable to complete the procedure correctly, have the student review the materials and try again.

  Product evaluation—Once the student has satisfactorily completed the procedure, rate the student product (outcome) using the criteria that are provided as part of the job sheet. If the student's product is unacceptable, have the student review the materials and submit another product for evaluation.

  Two sample performance evaluation keys have been provided below. Many other keys are available. Select one rating (grading scale) that best fits your program needs.

  Sample A

  4—**Skilled**—Can perform job with no additional training.
  3—**Moderately skilled**—Has performed job during training program; limited additional training may be required.
  2—**Limited skill**—Has performed job during training program; additional training is required to develop skill.
  1—**Unskilled**—Is familiar with process, but is unable to perform job.
  0—**No exposure**—No information or practice provided during training program.

  Sample B

  Yes—Can perform job with no additional training.
  No—Is unable to perform job satisfactorily.

- Give and evaluate the posttest.
- Meet individually with students to evaluate their progress through this unit of instruction and indicate to them possible areas of improvement.
- Reteach and retest as required.

Suggested Activities

Resources Used in Developing This Unit

Print Media

- Clark, Elton, et al. *Diesel Fundamentals.* Stillwater, OK: Mid-America Vocational Curriculum Consortium, Inc., 1988.
- Dagel, John F. *Diesel Engine and Fuel System Repair*, 4th ed. Upper Saddle River, NJ: Prentice Hall, 1994.
- Espenschied, Roland F. *Diesel Engines.* Athens, GA: American Association for Vocational Instructional Materials, 1990.
- *Fundamentals of Service: Engines*, 7th ed. Moline, IL: Deere and Company, 1991.
- *Rebuild Manual, Cummins Diesel 10 Litre Engines.* Columbus, IN: Cummins Engine Co., 1984.
- Schultz, Erich J. *Diesel Mechanics*, 4th ed. Dallas, TX: Glencoe/McGraw-Hill, 1998.
- *Series 60 Service Manual.* Detroit, MI: Detroit Diesel Corp., 1995.
- *Service Manual, 3176B Diesel Truck Engine.* Peoria, IL: Caterpillar, Inc., 1995.
- *Service Manual, 3600 Series Engines.* Peoria, IL: Caterpillar, Inc.

Note: Engine service manuals can be ordered through the local dealership.

Suggested Supplemental Resources

Print Media

- *Lubricating Oil Systems—Troubleshooting.* (3387003) Available as booklet, slide set, or audio tape.
- *Filter Plugging—Lubrication System.* (3387079) Available as booklet, slide set, or audio tape.
- *Demand Flow and Cooling Lubrication System.* (3387111) Available as booklet, slide set, or audio tape.
- *Lubrication and Filtration.* (3387113) Available as booklet, slide set, or audio tape.

The above are available from your local Cummins Engine Company dealer/distributor or call:

Cummins Engine Company Customer Relations
800-345-5654 or 502-453-8549 or for more information call 1-800-DIESELS

- *Principles of Lubrication* (SEBV0568), 24-page book. Available from your local CAT dealer or write the following for more information:

  Caterpillar Service Training
  600 W. Washington St., Bldg. JJ
  East Peoria, IL 61630

- *Maintenance and Lubrication Service Manual.* (3-101) Available from:

  Mack Trucks, Inc.
  2100 Mack Boulevard
  P.O. Box M
  Allentown, PA 18195-5000
  610-439-3011

- *Used Lubricating Oil Analysis Technician's Guide*, 7SE398-9507. 11-page booklet.

- *Lubricating Oil, Fuel, and Filters, Engine Requirements*, 7SE270-9603. 18-page booklet.

  The above are available from your local Detroit Diesel distributor/dealer or contact the national office for more information:

  Detroit Diesel Corporation
  13400 Outer Driver, West
  Detroit, MI 48239-4001
  Phone: 313-592-5000 or Fax: 313-592-7288

- *Fuels, Lubricants, Coolants, and Filters.* A training guide to the hows and whys of modern fuels, lubricants, and coolants. Available from:

  John Deere Publishing
  5440 Corporate Park
  Davenport, IA 52807
  800-522-7448
  http://www.deere.com

Suggested Activities

Electronic Media

- *Preventive Maintenance Unit Four: Lubricating System* video (BP-A374-VW). Shows checking for leaks, oil changes, filter changes, and types of filters. 1992.

- *The Care and Feeding of Machines* video (NIM-290-VW). Covers friction, how oil and grease overcome friction, viscosity, and proper lubricants.

  The above are available from:

  NIMCO
  102 Hwy. 81 North
  P.O. Box 9
  Calhoun, KY 42327-0009
  Phone: 800-962-6662 or Fax: 502-273-5844
  http://www.nimcoinc.com

- *Diesel Mechanics III Series*

  — *6.2L Diesel Engine Lubrication and Emission Controls.* VHS, 18 minutes

  — *Cummins NH-855 Flywheel and Oil Pump.* VHS, 12 minutes

  — *Diesel Fuel and Lubrication Recommendations.* VHS, 15 minutes

  These tapes are available singly or as part of multi-unit training modules from:

  Thomson Learning
  P.O. Box 6904
  Florence, KY 41022-6904
  Tel: 1-800-354-9706
  Email: esales@thomsonlearning.com

Written Test

Name ______________________________

Date ______________________ Score __________

Objective 1

Match terms related to lubrication systems with their correct definitions. Definitions continue on the next page.

1. Additives
2. Antidrain check valve
3. American Petroleum Institute (API)
4. American Society for Testing and Materials (ASTM)
5. Contaminant
6. Filter
7. Gallery
8. Inhibitor
9. Military specifications (MIL)
10. Multigrade oil
11. Oil pan
12. Particulate
13. Pressure gauge
14. Society of Automotive Engineers (SAE)
15. Strainer
16. Temperature gauge
17. Viscometer
18. Viscosity

_____ a. Oil specifications prepared by the federal government for specific military applications

_____ b. Prevents oil from draining out of the filters and back into the oil pan when the engine is stopped

_____ c. Any unwanted material in a fluid or lubricant

_____ d. Device that removes contaminants from fluids or lubricant

_____ e. Measure of a fluid's resistance to flow (at a given temperature)

_____ f. Coarse filter usually designed to prevent large items such as rocks and bolts from entering the system

_____ g. Indicates lubrication system pressure when the engine is running

_____ h. Substance made up of minute separate particles

_____ i. Oil that has been modified to behave as a light oil in cold temperatures, while acting as a heavy oil when hot

_____ j. Reservoir for engine oil; provides a surface for heat transfer from the hot oil to the atmosphere

_____ k. Association that developed a rating system for oil viscosity

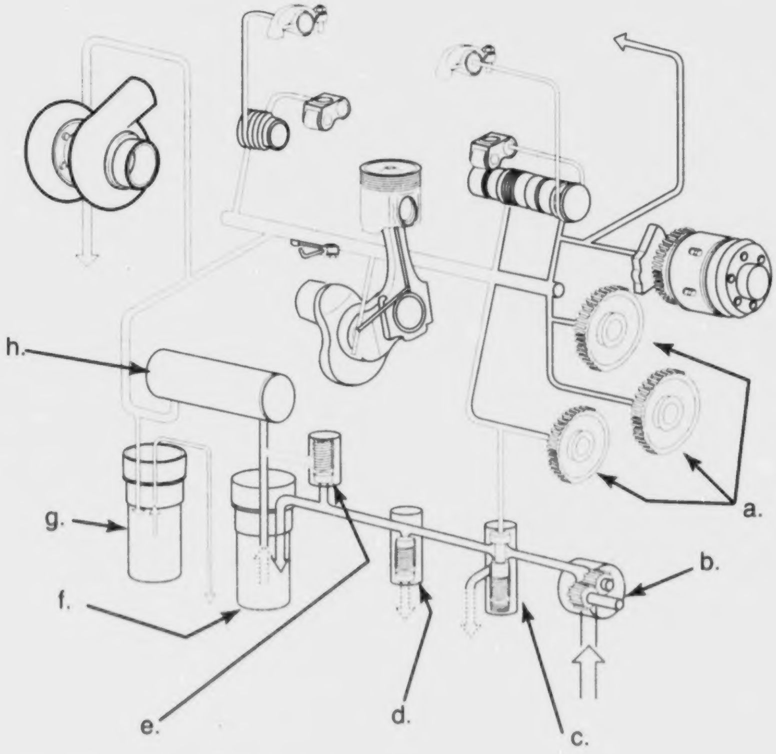
_____ l. Pipe or passageway in the engine used to carry engine oil from one area to another

_____ m. Association that issues engine oil classifications based on performance during standardized tests

_____ n. Chemical which dissolves in water to form a rustproof film on metal

Objective 2

Identify the basic components of a lubrication system. Write your answers in the blanks provided.



Courtesy of Cummins Engine Company, Inc.

a. ______________________ b. ______________________

c. ______________________ d. ______________________

e. ______________________ f. ______________________

g. ______________________ h. ______________________

Objective 3

Match the lubrication system components with their correct functions.

1. Bypass valve
2. Differential pressure valve
3. High pressure relief valve
4. Oil cooler
5. Oil galleries
6. Oil pump
7. Pressure regulator valve
8. Thermostat

_____ a. Diverts some of the oil from the oil pump directly back to the oil pan when system pressure rises above a set point

_____ b. Passageways cast in the block that supply oil to the crankshaft main bearings, camshaft bearings, oil cooler, oil filter, cam followers, and rocker arms

_____ c. Diverts oil flow around the oil filter and/or the oil cooler when system pressure rises above a set point due to cold, thick oil, or a clogged component

_____ d. Spring-loaded valve that limits the maximum system operating pressure

_____ e. Pulls oil from the oil pan, pressurizes it, and sends it to the oil filter, oil cooler, and main supply galleries

_____ f. Heat exchanger that transfers heat from the oil to either ambient air or engine coolant

_____ g. Senses pressure drop between the filter inlet and outlet; when the difference reaches a certain level, the valve allows oil to bypass the dirty filter

Objective 4

Match the basic types of oil filters with their correct descriptions of operation.

1. Bypass
2. Centrifugal bypass (spinner)
3. Combination full flow/bypass
4. Full flow

_____ a. Uses both a full flow filter and a bypass filter.

_____ b. All engine oil travels directly from the pump to the filter, before being sent to the oil galleries.

_____ c. Unfiltered oil travels directly from the pump to the oil galleries. Approximately 10% of the oil is diverted to the oil filter.

_____ d. Ten percent of the unfiltered oil is bypassed to the prefilter. Unfiltered oil enters the main cavity of the prefilter, which is spinning at about 4,000 rpm. Filtered oil leaves the cavity through jets and flows back to the crankcase.

Written Test

Objective 5

Distinguish between the basic oil pump designs and their operation by placing a "G" next to gear type designs and an "R" next to rotor type designs.

_____ a. Offset rotation of the inner rotor pulls oil into the pump.

_____ b. Oil is pulled into the pump and pressurized by the rotation of the gears.

_____ c. Oil is carried through the pump in the spaces between the inner rotor and the outer rotor ring.

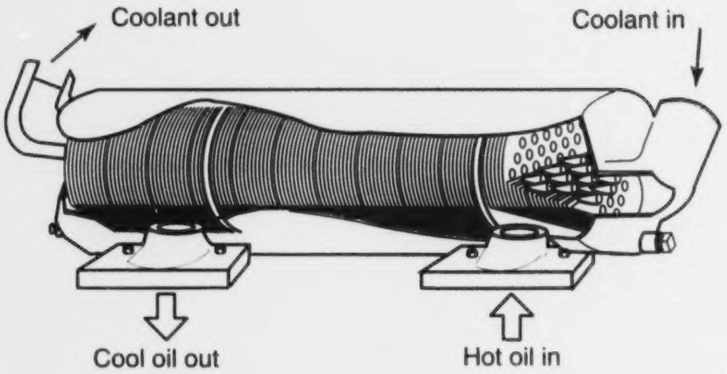
_____ d. Intermeshing teeth prevent backflow through the pump and loss of pressure.

_____ e. The oil stream is carried by the gear teeth around to the outlet side of the pump.

_____ f. Intermeshing rotor lobes prevent backflow through the pump.

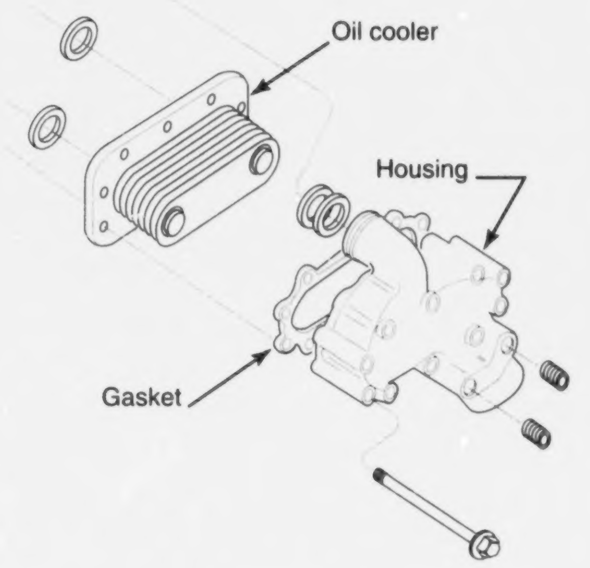
Objective 6

Identify the following basic oil cooler designs. Write your answers in the blanks provided.



Courtesy of Cummins Engine Company, Inc.

a. ______________________________



Courtesy of Cummins Engine Company, Inc.

b. ______________________________

Objective 7

Distinguish among types of oil coolers according to descriptions of their operation by placing a "P" next to plate types and a "B" next to bundle types.

_____ a. Coolant flows around the plates, absorbing the heat and transferring it to the radiator.

_____ b. Oil flows around the tubes.

_____ c. Coolant flows through the tubes, absorbing the heat and transferring it to the radiator.

_____ d. Oil flows through a series of flat plates, releasing heat to the plates.

Objective 8

List four sources of oil contamination.

a. ______________________________

b. ______________________________

c. ______________________________

d. ______________________________

Written Test

Objective 9

Complete statements concerning lubrication system monitor operation by filling in the blanks with the correct answers.

a. Oil pressure indicator has a sensor that responds to oil pressure changes by varying the ____________________ in the circuit.

b. High oil pressure causes high current flow, which causes a ____________________ reading on the gauge.

c. Oil pressure alarm (Switchgage™) operates in the following manner: If oil pressure falls off, the sensor sends a low reading to the Switchgage™. As the Switchgage™ indicator needle drops, it passes a preselected low pressure limit, triggering a magnetic switch inside the gauge. The switch energizes a relay, closing the _______ _______ _______. Fuel flow to the injector pump stops, and so does the engine.

Objective 10

Complete statements concerning API use codes by circling the correct answers.

a. The first alpha character in an API code designates **(engine, environment)** type.

b. The **(second, third)** alpha character designates the level of protection offered by the oil.

c. The higher the letter designation, the **(lower, higher)** the level of protection.

Objective 11

Discuss two factors to consider when choosing an engine oil.

a. ____

____

b. ____

____

***Permission to duplicate this test is granted.**

Answers to Written Test

Objective 1

a. 9
b. 2
c. 5
d. 6
e. 18
f. 15
g. 13
h. 12
i. 10
j. 11
k. 14
l. 7
m. 3
n. 8

Objective 2

a. Idler gears
b. Oil pump
c. Pressure regulator valve
d. High pressure relief valve
e. Full flow filter bypass valve
f. Full flow filter
g. Bypass filter
h. Oil cooler

Objective 3

a. 3
b. 5
c. 1
d. 7
e. 6
f. 4
g. 2

Objective 4

a. 3
b. 4
c. 1
d. 2

Objective 5

a. R
b. G
c. R
d. G
e. G
f. R

Objective 6

a. Bundle type
b. Plate type

Objective 7

a. P
b. B
c. B
d. P

Answers to Written Test

Objective 8

Any four of the following:

a. Dirt/dust in containers used to transfer lubricants from storage to engine
b. Water/condensation in storage container(s)
c. Airborne dust ingested by engine
d. Improper engine warm-up
e. Coolant leakage into crankcase
f. Oxidation
g. Carbon particles
h. Engine wear
i. Fuel dilution

Objective 9

a. Resistance
b. High
c. Fuel shutoff valve

Objective 10

a. Engine
b. Second
c. Higher

Objective 11

Any two of the following:

a. Manufacturer's minimum requirements for the engine series being used
b. Typical operating environment for the engine
c. Fuel quality and grade
d. Availability of brands meeting specifications
e. Cost

Prerequisites:
1-A and 2-A

Learning Activities Sheet

Student Name ______________________________

Place a checkmark in the appropriate box as you complete each of the steps below.

☐ 1. **Take** Pretest provided by instructor. After test has been evaluated, follow instructor's recommendations.

☐ 2. **Read** Objective Sheet.

☐ 3. **Study** Information Sheet, Objectives 1 through 5.

☐ 4. **Observe** Demonstration of procedures to be used in completing Job Sheet 1.

☐ 5. **Do** Job Sheet 1, "Service and Install Oil Pump and Oil Pump Drive Components."

☐ 6. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 7. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 1 and repeat steps 3 through 6.

☐ 7. **Study** Information Sheet, Objectives 6 and 7.

☐ 8. **Observe** Demonstration of procedures to be used in completing Job Sheet 2.

☐ 9. **Do** Job Sheet 2, "Service and Inspect Lubrication System Screens and Pipes."

☐ 10. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 11. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 2 and repeat steps through 10.

☐ 11. **Study** Information Sheet, Objectives 8 and 9.

☐ 12. **Observe** Demonstration of procedures to be used in completing Job Sheet 3.

Learning Activities Sheet

☐ 13. **Do** Job Sheet 3, "Service and Inspect Oil Pressure Regulator Valve and Bypass Valve."

☐ 14. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 15. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 3 and repeat steps 11 through 14.

☐ 15. **Study** Information Sheet, Objectives 10 and 11.

☐ 16 **Observe** Demonstration of procedures to be used in completing Job Sheet 4.

☐ 17. **Do** Job Sheet 4, "Service and Inspect Oil Cooler and Lines"

☐ 18. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 19. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 4 and repeat steps 15 through 18.

☐ 19. **Check** With instructor for any additional assignments to be completed.

☐ 20. **Do** Additional assignments listed below.

____

____

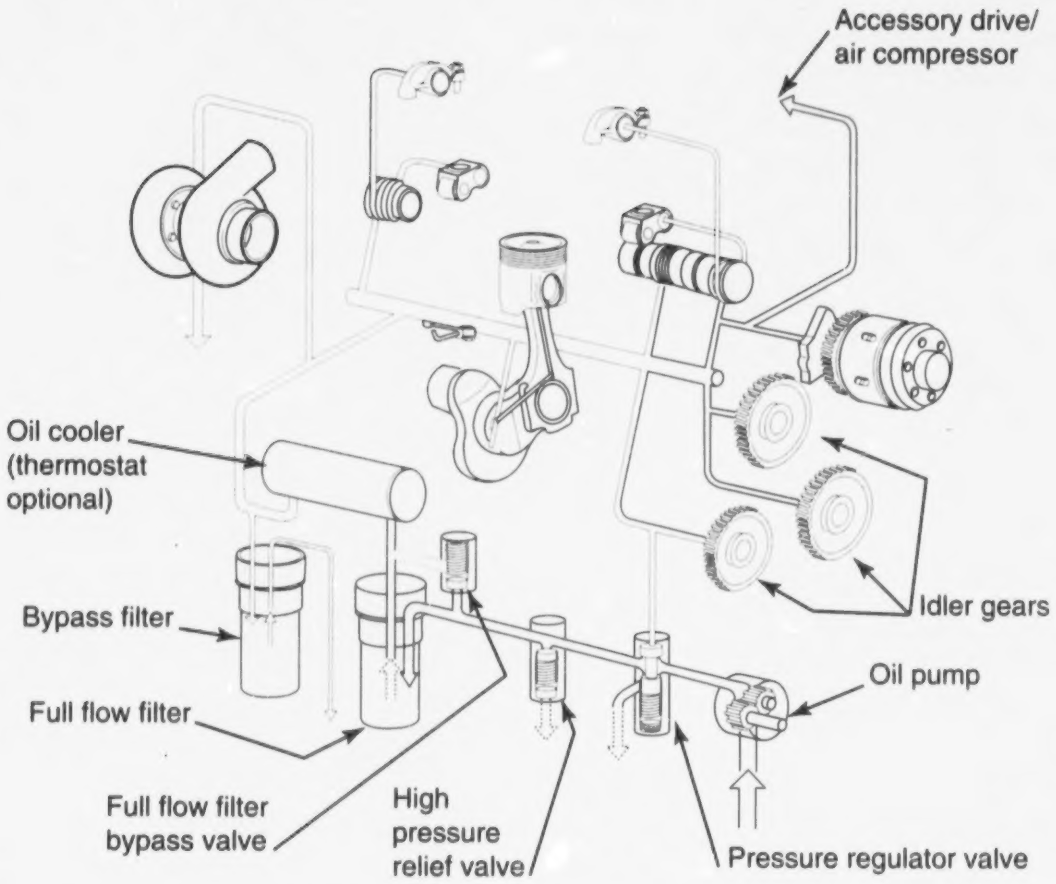
____

☐ 21. **Take** Posttest provided by instructor. After test has been evaluated, follow instructor's recommendations.

☐ 22. **Stop** Have instructor evaluate your unit performance. If the evaluation is satisfactory, proceed to next learning activities sheet. If evaluation is not satisfactory, ask instructor for further instructions.

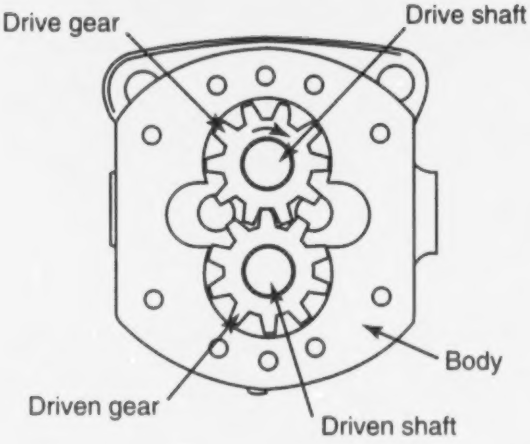
***Permission to duplicate this form is granted.**

Lubrication System Components

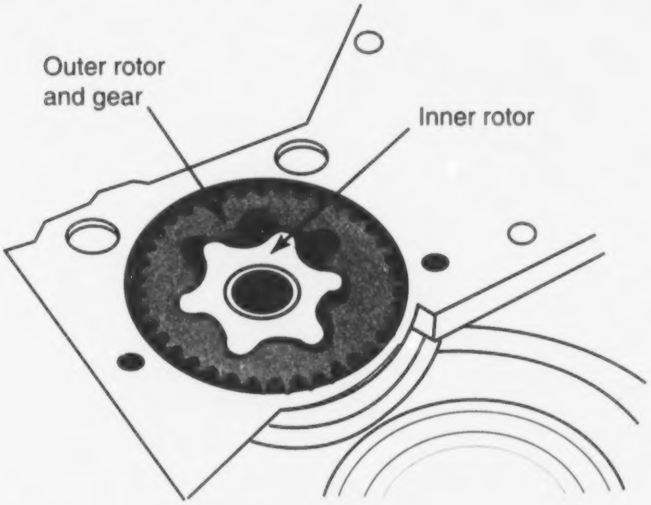

Accessory drive/
air compressor
Oil cooler
(thermostat
optional)
Idler gears
Oil pump
Bypass filter
Full flow filter
Full flow filter
bypass valve
High
pressure
relief valve
Pressure regulator valve

Courtesy of Cummins Engine Company, Inc.

Basic Oil Pump Designs


Drive gear
Drive shaft
Body
Driven gear
Driven shaft

Gear Type


Outer rotor and gear
Inner rotor

Rotor Type

Courtesy of Detroit Diesel Corporation

Basic Oil Cooler Designs

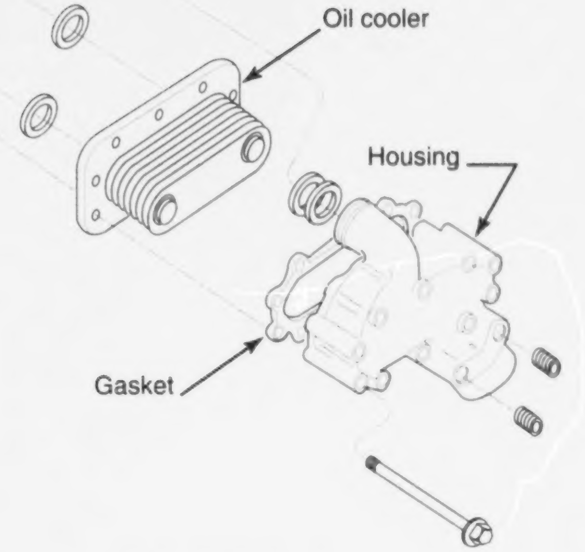
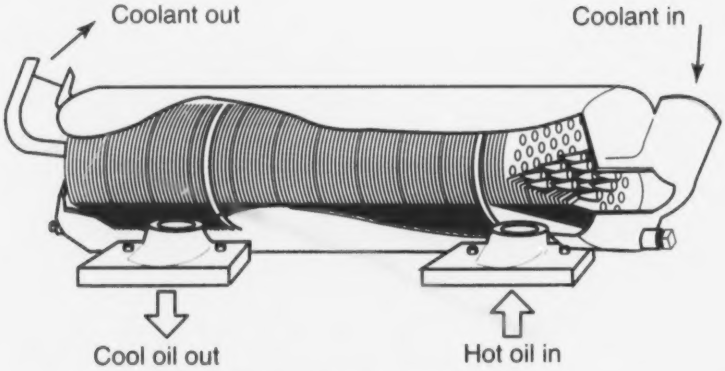

Oil cooler
Housing
Gasket

Plate Type

Courtesy of Detroit Diesel Corporation


Coolant out
Coolant in
Cool oil out
Hot oil in

Bundle Type

Courtesy of Cummins Engine Company, Inc.

TM 3

Unit 2-B Cooling Systems

Unit Contents

Teacher Components

Teacher Page

Suggested Activities 2B–3
Written Test 2B–9
Answers to Written Test 2B–17
Learning Activities Sheet 2B–19

Transparency Masters

1—Common Types of Cooling Systems 2B–21
2—Common Types of Radiators 2B–23
3—Parts of a Water Pump 2B–25

Student Components

Student Page

Objective Sheet 2B–3
Information Sheet 2B–5

Job Sheets

1—Flush, Refill, and Bleed Coolant System 2B–15
2—Inspect Water Pump, Belts, and Hoses 2B–19
3—Check Operation of Fan Assembly and Controls 2B–23
4—Test Operation of Thermostat Installed in Engine 2B–27
5—Test Operation of Thermostat on the Bench 2B–31
6—Check Operation and Accuracy of Temperature Indicating System 2B–35

Suggested Activities

Instructional Plan

Preparation

- Read the unit carefully and plan for instruction.
- Review "Teaching Suggestions." Plan for classroom activities.
- Plan your presentation to take advantage of student learning styles and to accommodate special-needs students.
- Prepare classroom. Put up posters and charts and display articles and other references related to this unit.
- Obtain films, videotapes, and other resources to supplement instruction of this unit. See "Resources Used in Developing This Unit" and "Suggested Supplemental Resources" for more information.
- For self-paced instruction, review Learning Activities Sheet. Modify as appropriate to include additional activities and/or resources available in your classroom. Make one copy for each student.
- Make transparencies from the transparency masters included in this unit. These appear in the teacher edition only.

Delivery and Application

Unit Introduction (self-paced instruction)

- Provide student with Learning Activities Sheet and unit of instruction.
- Review unit contents with student.
- Have the student complete the steps in the learning activities sheet.

Unit Introduction (group instruction)

- Provide students with unit of instruction.
- Discuss unit and specific objectives.
- Discuss the information sheet. Implement teaching plan to localize, supplement, and personalize the unit. Reinforce basic academic and workplace skills when applicable.

Suggested Activities

- Discuss and demonstrate the job sheets. Make sure all required tools, equipment, and materials are available. Review with students the criteria for evaluation of these activities and the rating scale that will be used to indicate job performance.

Teaching Suggestions

- Discuss the different types of cooling systems (air-cooled and liquid-cooled), and point out the advantages and disadvantages of each type and the most common applications of the two types of cooling systems.
- Have students identify the different types of cooling systems (air-cooled and liquid-cooled) using vehicles/equipment available in the shop. Also have them identify the main components and features.
- Use an actual cooling system on a vehicle available in the shop or a mock-up of a cooling system to show the basic operation of an air-cooled or liquid-cooled engine. You may want to use cards with numbers so you can tape on the parts as you discuss the steps in the operation.
- Discuss the effects of having an engine that is too hot or too cold as outlined in Objective 6.
- Discuss the most common problems that you have encountered with cooling systems. Describe what may be required to solve each problem.
- Show examples of different types of radiators. Discuss their similarities and differences. Discuss the most common applications for each type.
- Show examples of water pumps and their drives (belts or gears). Let students examine them to see the physical differences.
- Show examples of coolant filters, conditioners, additives, and antifreeze. Discuss their uses. Then demonstrate the procedures for basic preventive maintenance on these components.
- Discuss the purpose and operation of a typical radiator cap as outlined in Objectives 14 and 15.

Evaluation

- Make copies of the written test. Add or modify test items as needed. The written test serves as both a pretest and posttest to assist in measuring each student's competency gains.
- Give and evaluate pretest. Modify lesson plan to include additional instruction for those areas where students were deficient.

- Evaluate the job sheets. When the student is ready to perform a specific task, obtain a copy of the job sheet which may be found in the student edition. Then observe the student performing the procedure.

  Process evaluation—Place a mark in the box to the left of each designated checkpoint if the student has satisfactorily completed the process step(s) for each checkpoint area. If the student is unable to complete the procedure correctly, have the student review the materials and try again.

  Product evaluation—Once the student has satisfactorily completed the procedure, rate the student product (outcome) using the criteria that are provided as part of the job sheet. If the student's product is unacceptable, have the student review the materials and submit another product for evaluation.

  Two sample performance evaluation keys have been provided below. Many other keys are available. Select one rating (grading scale) that best fits your program needs.

  Sample A

  4—**Skilled**—Can perform job with no additional training.
  3—**Moderately skilled**—Has performed job during training program; limited additional training may be required.
  2—**Limited skill**—Has performed job during training program; additional training is required to develop skill.
  1—**Unskilled**—Is familiar with process, but is unable to perform job.
  0—**No exposure**—No information or practice provided during training program.

  Sample B

  Yes—Can perform job with no additional training.
  No—Is unable to perform job satisfactorily.

- Give and evaluate the posttest.

- Meet individually with students to evaluate their progress through this unit of instruction and indicate to them possible areas of improvement.

- Reteach and retest as required.

Resources Used in Developing This Unit

Print Media

- Clark, Elton, et al. *Diesel Fundamentals*. Stillwater, OK: Mid-America Vocational Curriculum Consortium, Inc., 1988.

- Dagel, John F. *Diesel Engine and Fuel System Repair*, 4th ed. Upper Saddle River, NJ: Prentice Hall, 1994.

- Espenschied, Roland F. *Diesel Engines.* Athens, GA: American Association for Vocational Instructional Materials, 1990.
- *Fundamentals of Service: Engines*, 7th ed. Moline, IL: Deere and Company, 1991.
- *Rebuild Manual, Cummins Diesel 10 Litre Engines.* Columbus, IN: Cummins Engine Co., 1984.
- *Series 60 Service Manual.* Detroit, MI: Detroit Diesel Corp., 1995.
- *Service Manual, 3176B Diesel Truck Engine.* Peoria, IL: Caterpillar, Inc., 1995.
- *Service Manual, 3600 Series Engines.* Peoria, IL: Caterpillar, Inc., 1995.

Note: Engine service manuals can be ordered through the local dealership.

Suggested Supplemental Resources

Print Media

- *Cooling Systems—Troubleshooting.* (3387030) Available as booklet, slide set, or audio tape.
- *Cooling System.* (3387156) Available as booklet, slide set, or audio tape.
- *Coolant Additives and Filtration.* (3387251) Available as booklet, slide set, or audio tape.
- *Demand Flow and Cooling Lubrication System.* (3387111) Available as booklet, slide set, or audio tape.
- *Low Flow Cooling Familiarization.* (3387275) Available as booklet, slide set, or audio tape.
- *Optimized Aftercooling and Low Flow Radiators.* (3387315 or 3387406). Available as booklet, slide set, audio tape, as well as VHS videotape.
- *Cooling System Maintenance.* (3387460-63). Available as booklet, slide set, audio tape, as well as VHS videotape.
- *Heavy Duty Coolant/SCA Maintenance.* (3387910-13). Available as booklet, slide set, audio tape, as well as VHS videotape.

The above are available from your local Cummins Engine Company dealer/distributor or call:

Cummins Engine Company Customer Relations
800-345-5654 or 502-453-8549 or for more information call 1-800-DIESELS

- *Cool It! Components* (SDF-016). Self-paced training module.
- *Cool It! Fundamentals* (SDF-017). Self-paced training module.

The above are available from:

Freightliner Corporation
Technical Training Department
5169 N. Lagoon Avenue
Portland, OR 97217

- *Engine Cooling System Service Manual.* (7.0) Available from:

Mack Trucks, Inc.
2100 Mack Boulevard
P.O. Box M
Allentown, PA 18195-5000
610-439-3011

- *Fuel/Lube Oil Specifications for Detroit Diesel Engines* (07SE 0270)
- *Coolant for DDC Engines* (07SE 0298)

The above are available from your local Detroit Diesel distributor/dealer or order from the following:

Robot Literature Distribution
12085 Dixie
Redford, MI 48239
Phone: 313-255-9300 or Fax: 313-255-7680

Electronic Media

- *How to Use Cooling System Diagnostic Tools* (SEVN9092-9097), a series of six videos (length varies from 12 to 28 minutes).
- Diagnostic Tool Presentation (SESV1438), 72 slides that show how selected diagnostic tools are connected and used.

The above are available from your local CAT dealer or write the following for more information:

Caterpillar Service Training
600 W. Washington St., Bldg. JJ
East Peoria, IL 61630

Suggested Activities

- *Preventive Maintenance Unit Three: Cooling System* video (BP-A373-VW). Discusses heat dissipation, coolant levels, fans, and filters. 1992. Available from:

  NIMCO
  102 Hwy. 81 North
  P.O. Box 9
  Calhoun, KY 42327-0009
  Phone: 800-962-6662 or Fax: 502-273-5844
  http://www.nimcoinc.com

- *Engine Diagnosis and the Cooling System* (VH1-101PT), 11-minute videotape—Discusses the steps in engine diagnosis and common cooling system problems and failures. Available from:

  Dana Corporation
  Publication Services
  P.O. Box 453
  Toledo, OH 43692-0453
  Phone: 419-535-4285 or Fax: 419-535-4396

Written Test

Name ____

Date ______________________________ Score __________

Objective 1

Match terms related to cooling systems with their definitions.

1. Antifreeze
2. Bypass
3. Cavitation erosion
4. Coolant
5. Deaeration circuit
6. Dropout
7. Ethylene glycol
8. Fill line
9. Inhibitor
10. Manual bleeds
11. Permanent antifreeze
12. Water jacket
13. Water manifold

_____ a. Connects thermostat housing or water manifold to the surge tank; prevents cavitation by allowing bubbles and small amounts of trapped air to escape

_____ b. Tube connecting different parts of the water jacket

_____ c. Antifreeze/water mixture circulating in the engine cooling system

_____ d. Chemical compound that is commonly used as an antifreeze

_____ e. Design that routes coolant around the closest thermostat and directly back to the water pump inlet

_____ f. Chemical additive in antifreeze that prevents rust and pitting

_____ g. Part of the casting that surrounds the cylinder head and engine block; contains the coolant as it passes over the cylinder liners and combustion chamber

_____ h. Can be opened during system fill to allow trapped air to escape

_____ i. Material added to coolant to prevent freezing

_____ j. Pitting caused by vapor bubbles

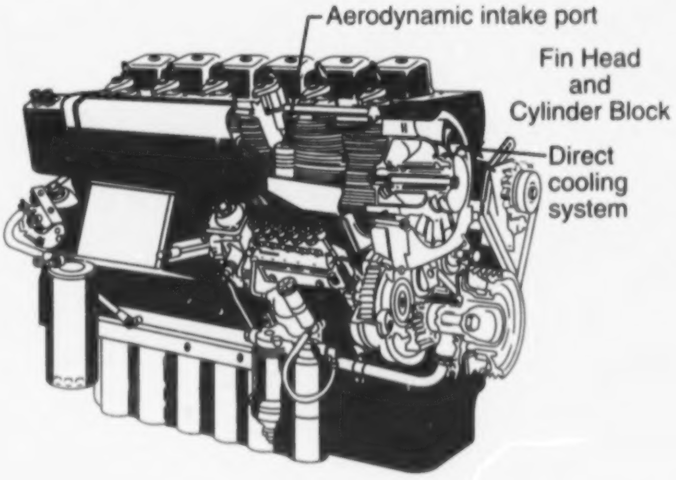
_____ k. Connects water pump to upper radiator tank; prevents cavitation by maintaining positive pressure inside the pump

_____ l. Sludge or deposits that form in or on cooling system components; caused by excessive amounts of chemicals in the engine coolant

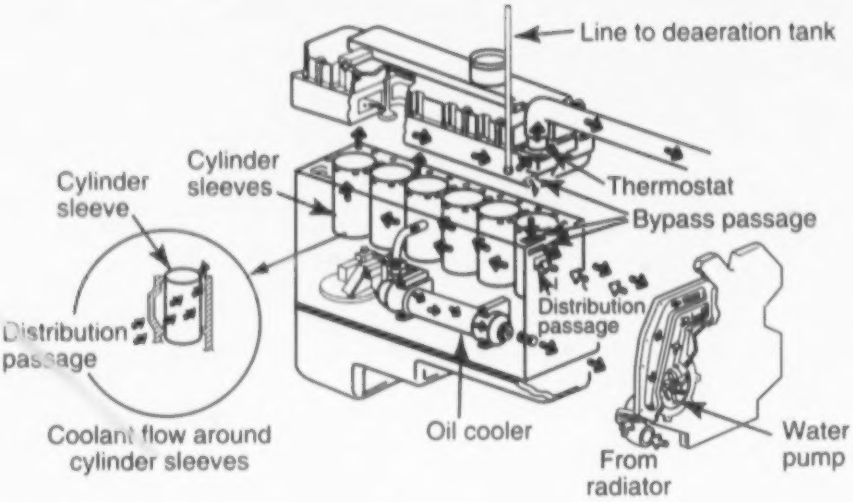
Written Test

Objective 2

Identify the following common types of cooling systems. Write your answers in the blanks provided.


Aerodynamic intake port
Fin Head and Cylinder Block
Direct cooling system

a. ______________________________


Line to deaeration tank
Cylinder sleeve
Cylinder sleeves
Thermostat
Bypass passage
Distribution passage
Distribution passage
Coolant flow around cylinder sleeves
Oil cooler
From radiator
Water pump

Courtesy of Cummins Engine Company, Inc.

b. ______________________________

Objective 3

Match cooling system components for an air-cooled engine with their correct functions.

1. Cooling fins
2. Fan
3. Shroud
4. Thermostat

_____ a. Controls the amount of air flowing from the fan; speeds engine warm-up and maintains a safe operating temperature

_____ b. Sheet metal cover that contains and guides the cooling air around the engine cylinders and cylinder head(s)

_____ c. Absorb combustion and friction heat from the engine cylinders and cylinder head(s) and dissipate it into the airstream

_____ d. Provides a steady supply of ambient temperature air for engine cooling

Objective 4

Match cooling system components for a liquid-cooled engine with their correct functions. Functions continue on the next page.

1. Coolant
2. Coolant filter
3. Expansion tank
4. Fan
5. Fan belts
6. Hoses
7. Radiator
8. Radiator pressure cap
9. Thermostat
10. Water pump

_____ a. Traps and collects impurities, sand, and scale; sometimes contains a water conditioner cartridge to soften the water in the cooling system

_____ b. Circulates coolant through the radiator and water jacket

_____ c. Heat exchanger that absorbs heat from the engine coolant and transfers it to the atmosphere

_____ d. Separate tank that collects and holds the expanding coolant; as the engine cools, the coolant is drawn back into the radiator

_____ e. Mixture of antifreeze and water that absorbs engine heat

_____ f. Device that maintains stable engine operating temperature by controlling coolant flow through the engine

_____ g. Transmit engine motion to drive the fan and water pump

_____ h. Allows the cooling system to operate under pressure; raises the effective boiling point of the coolant and prevents coolant loss from boil-over

_____ i. Flexible connections between the engine and other parts of the cooling system

_____ j. Forces air through the radiator core to speed heat transfer

Objective 5

Distinguish between the operation of an air-cooled and liquid-cooled engine by placing an "A" next to statements describing air-cooled engines and an "L" next to statements describing liquid-cooled engines.

_____ a. During engine warm-up, cooling air is either restricted or rerouted until engine operating temperature is reached.

_____ b. Engine heat passes through the cylinder walls into the water jacket, where it is absorbed by the moving coolant.

_____ c. The water pump circulates coolant from the radiator to the water jacket surrounding the engine block and heads.

_____ d. Ambient temperature air is drawn in by cooling fan and forced through sheet metal shrouding.

_____ e. The shrouds direct the air over the finned surfaces of the cylinders and cylinder heads, collecting heat.

Objective 6

Describe the effects of incorrect temperature regulation.

a. Too hot

____

____

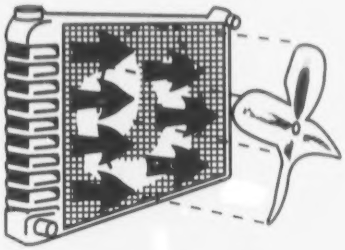
b. Too cold

____

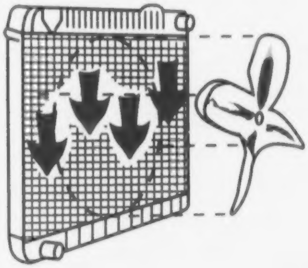
____

Objective 7

Identify the following common types of radiators. Write your answers in the blanks provided.



a. ______________________



b. ______________________

Objective 8

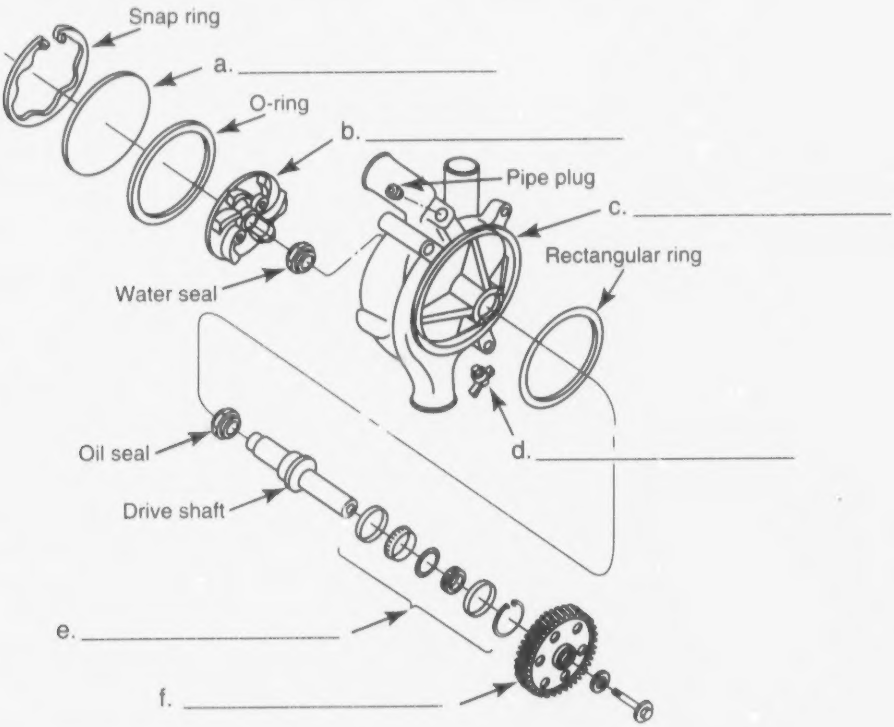
List the two types of drives for water pumps

a. ____

b. ____

Objective 9

Identify the following parts of a water pump. Write your answers in the blanks provided.

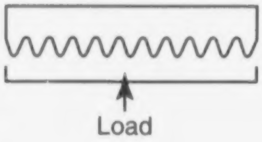

Snap ring
a. ______________________
O-ring
b. ______________________
Pipe plug
c. ______________________
Rectangular ring
Water seal
Oil seal
d. ______________________
Drive shaft
e. ______________________
f. ______________________

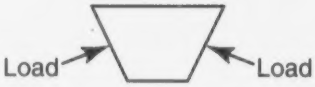
Courtesy of Detroit Diesel Corporation

Written Test

Objective 10

Identify the following types of drive belts. Write your answers in the blanks provided.





a. ____________________ b. ____________________

Objective 11

Match coolant items with their correct functions.

1. Coolant additives 2. Coolant conditioners 3. Coolant filters

_____ a. Soften the water to minimize scale build-up; contain rust inhibitors that provide a protective film around metal surfaces in the cooling system

_____ b. Trap and hold sand, scale, and rust particles

_____ c. Provide protection for cooling system components; minimize cavitation

Objective 12

Distinguish between types of antifreeze by placing an "E" next to inhibited ethylene glycol and a "P" next to inhibited propylene glycol:

_____ a. Boiling point raised to 257°F, and freezing point lowered to -27°F

_____ b. Highly toxic to plants, animals, and people

_____ c. Boiling point raised to 263°F, and freezing point lowered to -34°F

Objective 13

Select from the following list the characteristics of a suitable antifreeze by placing an "X" in the blanks next to the true statements.

_____ a. Allows coolant mixture to freeze

_____ b. Inhibits rust and corrosion

_____ c. Lowers the boiling point

_____ d. Is chemically stable.

_____ e. Resists foaming

_____ f. Does not absorb or conduct heat

Objective 14

List four purposes of a radiator cap.

a. ______________________________

b. ______________________________

c. ______________________________

d. ______________________________

Objective 15

Complete statements concerning typical radiator cap operation by circling the correct answers.

a. Cooling system at atmospheric pressure

- Vacuum valve is **(open, closed)**.
- Pressure relief valve is **(open, closed)**.

b. Cooling system operating at high load/high heat

- Vacuum valve is **(open, closed)**.
- Pressure relief valve **(opens, closes)** when system pressure exceeds cap rating; coolant is released into expansion tank.

c. System cool-down

- Vacuum valve **(opens, closes)** allowing coolant to return from expansion tank.
- Pressure relief valve is (open, closed).

***Permission to duplicate this test is granted.**

Answers to Written Test

Objective 1

a. 5
b. 13
c. 4
d. 7
e. 2
f. 9
g. 12
h. 10
i. 1
j. 3
k. 8
l. 6

Objective 2

a. Air
b. Liquid

Objective 3

a. 4
b. 3
c. 1
d. 2

Objective 4

a. 2
b. 10
c. 7
d. 3
e. 1
f. 9
g. 5
h. 8
i. 6
j. 4

Objective 5

a. A
b. L
c. L
d. A
e. A

Objective 6

a. Too hot—Any one of the following:
  - Insufficient clearance between moving parts
  - Accelerated wear on bearing surface
  - Scoring and seizure of pistons, rings, and valve stems
  - Power loss

b. Too cold—Any one of the following:
  - Accelerated wear on bearing surfaces and cylinder walls
  - Oil contamination
  - Sluge build-up in the crankcase
  - Poor fuel economy
  - Power loss

Objective 7

a. Cross-flow
b. Down-flow

Objective 8

a. Belt
b. Gear

Answers to Written Test

Objective 9

a. Water pump cover
b. Impeller
c. Water pump housing
d. Drain cock
e. Bearing assembly
f. Water pump drive gear

Objective 10

a. Poly V (serpentine)
b. V-belt

Objective 11

a. 2
b. 3
c. 1

Objective 12

a. P
b. E
c. E

Objective 13

b, d, e

Objective 14

Any four of the following:

a. Seals the radiator
    - Prevents entry of air, which causes corrosion
    - Prolongs the useful life of antifreeze and cooling system additives

b. Allows the cooling system to operate under positive pressure
    - Raises the effective boiling point of the coolant
    - Minimizes coolant loss
    - Minimizes cavitation erosion

c. Maintains system pressure at a preset level with the use of a pressure relief valve
    - Prevents damage to radiator core and hoses
    - Maintains consistent boiling point for coolant

d. Allows overflow coolant to reenter the radiator during cool-down with the use of a vacuum valve
    - Maintains correct coolant level in the radiator
    - Eliminates air pockets

Objective 15

a.
- Closed
- Closed

b.
- Closed
- Opens

c.
- Opens
- Closed

Prerequisites:
1-A, 2-A, and
1-B

Learning Activities Sheet

Student Name ______________________________

Place a checkmark in the appropriate box as you complete each of the steps below.

☐ 1. **Take** Pretest provided by instructor. After test has been evaluated, follow instructor's recommendations.

☐ 2. **Read** Objective Sheet.

☐ 3. **Study** Information Sheet, Objectives 1 through 5.

☐ 4. **Observe** Demonstration of procedures to be used in completing Job Sheet 1.

☐ 5. **Do** Job Sheet 1, "Flush, Refill, and Bleed Coolant System."

☐ 6. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 7. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 1 and repeat steps 3 through 6.

☐ 7. **Study** Information Sheet, Objectives 6 through 10.

☐ 8. **Observe** Demonstration of procedures to be used in completing Job Sheet 2.

☐ 9. **Do** Job Sheet 2, "Inspect Water Pump, Belts, and Hoses."

☐ 10. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 11. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 2 and repeat steps 7 through 10.

☐ 11. **Study** Information Sheet, Objectives 11, 12, and 13.

☐ 12. **Observe** Demonstration of procedures to be used in completing Job Sheet 3.

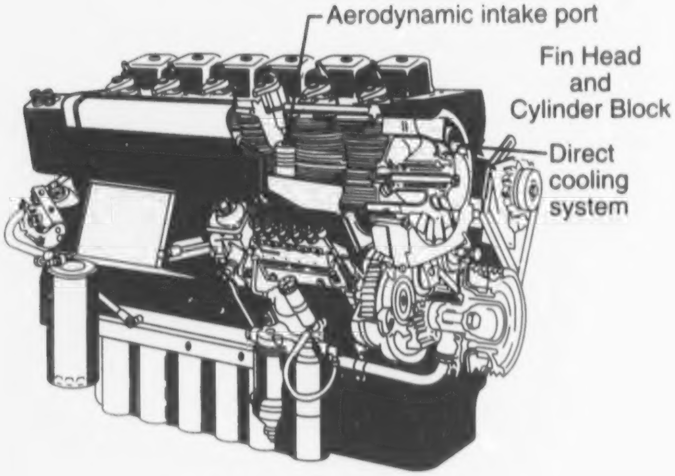
☐ 13. **Do** Job Sheet 3, "Check Operation of Fan Assembly and Controls."

Learning Activities Sheet

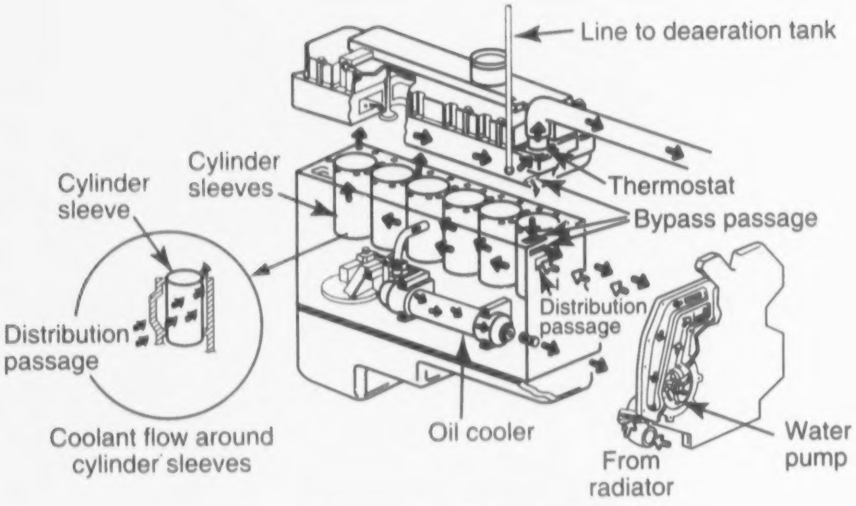
☐	14.	**Stop**	Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 15. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 3 and repeat steps 11 through 14.
☐	15.	**Study**	Information Sheet, Objectives 14 and 15.
☐	16.	**Observe**	Demonstration of procedures to be used in completing Job Sheets 4, 5, and 6.
☐	17.	**Do**	**Job Sheet 4,** "Test Operation of Thermostat Installed in Engine," **Job Sheet 5,** "Test Operation of Thermostat on the Bench," and **Job Sheet 6**, "Check Operation and Accuracy of Temperature Indicating System."
☐	18.	**Stop**	After completing each job sheet, have your instructor evaluate your performance. If the evaluation is satisfactory, continue to the next job sheet. If the evaluation is not satisfactory, study the procedure outlined in that job sheet, and redo the job sheet. After satisfactorily completing Job Sheets 4, 5, and 6, continue to step 19.
☐	19.	**Check**	With instructor for any additional assignments to be completed.
☐	20.	**Do**	Additional assignments listed below. ____________________ ____________________ ____________________
☐	21.	**Take**	Posttest provided by instructor. After test has been evaluated, follow instructor's recommendations.
☐	22.	**Stop**	Have instructor evaluate your unit performance. If the evaluation is satisfactory, proceed to next learning activities sheet. If evaluation is not satisfactory, ask instructor for further instructions.

***Permission to duplicate this form is granted.**

Common Types of Cooling Systems


Aerodynamic intake port
Fin Head and Cylinder Block
Direct cooling system

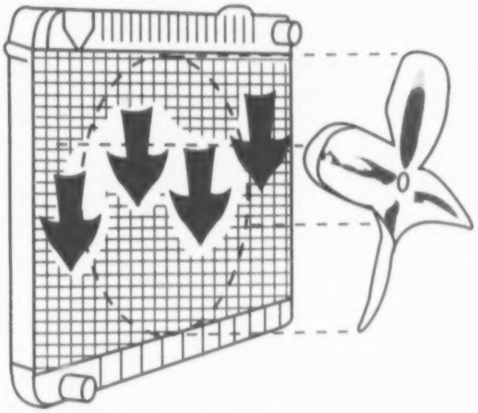
Air Cooled


Line to deaeration tank
Cylinder sleeves
Cylinder sleeve
Thermostat
Bypass passage
Distribution passage
Distribution passage
Coolant flow around cylinder sleeves
Oil cooler
From radiator
Water pump

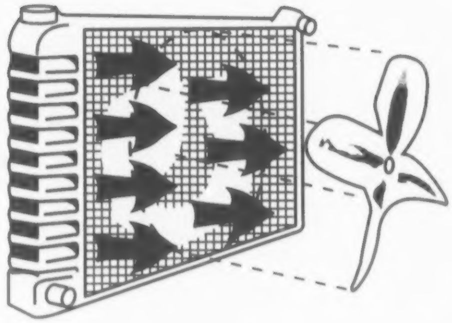
Liquid Cooled

Courtesy of Cummins Engine Company, Inc.

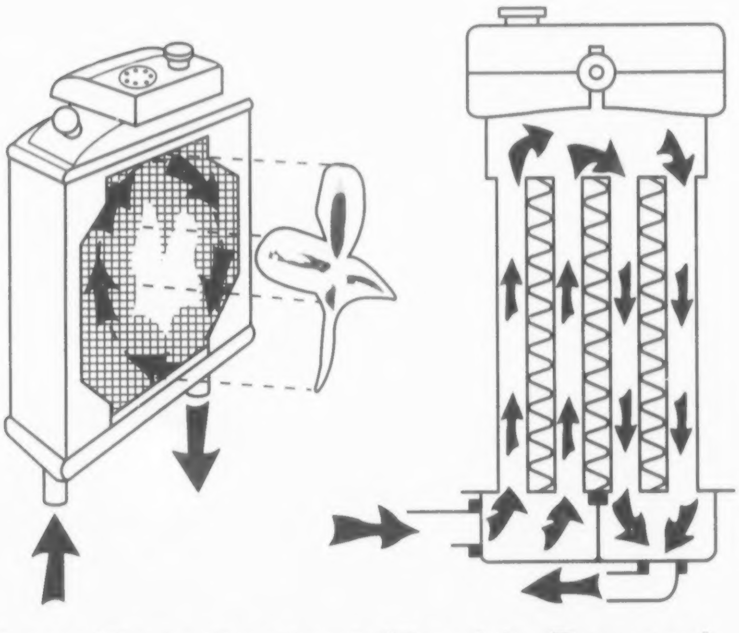
Common Types of Radiators



Down-Flow

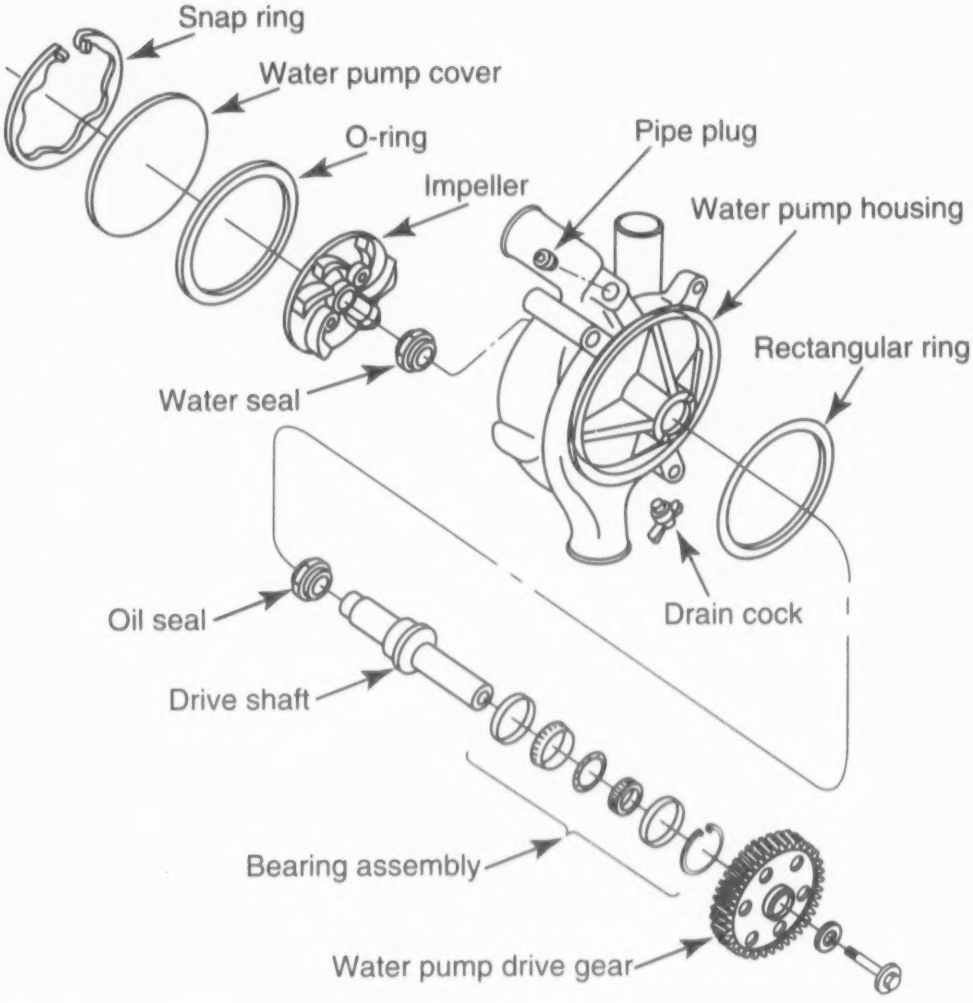


Cross-Flow



Low Flow Coolant (Double Bypass)

Parts of a Water Pump


Snap ring
Water pump cover
O-ring
Impeller
Pipe plug
Water pump housing
Rectangular ring
Water seal
Oil seal
Drain cock
Drive shaft
Bearing assembly
Water pump drive gear

Courtesy of Detroit Diesel Corporation

Unit Contents

Teacher Components

Teacher Page

Suggested Activities 3B-3

Written Test 3B-9

Answers to Written Test 3B-13

Learning Activities Sheet 3B-15

Transparency Master

1—Types of Cylinder Liners 3B-17

Student Components

Student Page

Objective Sheet 3B-3

Information Sheet 3B-5

Job Sheets

1—Pressure Test a Cylinder Block 3B-11
2—Disassemble and Clean a Cylinder Block 3B-15
3—Inspect a Cylinder Block 3B-19
4—Install New Camshaft Bushings 3B-27
5—Clean and Inspect Cylinder Bores 3B-31
6—Install Cylinder Liners and Set Liner Protrusion 3B-35

Suggested Activities

Instructional Plan

Preparation

- Read the unit carefully and plan for instruction.
- Review "Teaching Suggestions." Plan for classroom activities.
- Plan your presentation to take advantage of student learning styles and to accommodate special-needs students.
- Prepare classroom. Put up posters and charts and display articles and other references related to this unit.
- Obtain films, videotapes, and other resources to supplement instruction of this unit. See "Resources Used in Developing This Unit" and "Suggested Supplemental Resources" for more information.
- For self-paced instruction, review Learning Activities Sheet. Modify as appropriate to include additional activities and/or resources available in your classroom. Make one copy for each student.
- Make a transparency from the transparency master included in this unit. This appears in the teacher edition only.

Delivery and Application

Unit Introduction (self-paced instruction)

- Provide student with Learning Activities Sheet and unit of instruction.
- Review unit contents with student.
- Have the student complete the steps in the learning activities sheet.

Unit Introduction (group instruction)

- Provide students with unit of instruction.
- Discuss unit and specific objectives.
- Discuss the information sheet. Implement teaching plan to localize, supplement, and personalize the unit. Reinforce basic academic and workplace skills when applicable.
- Discuss and demonstrate the job sheets. Make sure all required tools, equipment, and materials are available. Review with students the criteria for evaluation of these activities and the rating scale that will be used to indicate job performance.

Suggested Activities

Teaching Suggestions

- Discuss the differences and similarities between liquid-cooled and air-cooled cylinder blocks. Point out the different components and applications.
- Make a display of the different types of cylinder liners (sleeves), and have students identify them.
- Discuss the characteristics of the different types of cylinder liners, including their advantages and disadvantages.
- Discuss the most common problems that you have encountered with cylinder blocks and abnormal sleeve wear. Describe what may be required to solve each problem.

Evaluation

- Make copies of the written test. Add or modify test items as needed. The written test serves as both a pretest and posttest to assist in measuring each student's competency gains.
- Give and evaluate pretest. Modify lesson plan to include additional instruction for those areas where students were deficient.
- Evaluate the job sheets. When the student is ready to perform a specific task, obtain a copy of the job sheet which may be found in the student edition. Then observe the student performing the procedure.

  Process evaluation—Place a mark in the box to the left of each designated checkpoint if the student has satisfactorily completed the process step(s) for each checkpoint area. If the student is unable to complete the procedure correctly, have the student review the materials and try again.

  Product evaluation—Once the student has satisfactorily completed the procedure, rate the student product (outcome) using the criteria that are provided as part of the job sheet. If the student's product is unacceptable, have the student review the materials and submit another product for evaluation.

Two sample performance evaluation keys have been provided below. Many other keys are available. Select one rating (grading scale) that best fits your program needs.

Sample A

4—**Skilled**—Can perform job with no additional training.
3—**Moderately skilled**—Has performed job during training program; limited additional training may be required.
2—**Limited skill**—Has performed job during training program; additional training is required to develop skill.
1—**Unskilled**—Is familiar with process, but is unable to perform job.
0—**No exposure**—No information or practice provided during training program.

Sample B

Yes—Can perform job with no additional training.
No—Is unable to perform job satisfactorily.

- Give and evaluate the posttest.
- Meet individually with students to evaluate their progress through this unit of instruction and indicate to them possible areas of improvement.
- Reteach and retest as required.

Resources Used in Developing This Unit

Print Media

- Clark, Elton, et al. *Diesel Fundamentals.* Stillwater, OK: Mid-America Vocational Curriculum Consortium, Inc., 1988.
- Dagel, John F. *Diesel Engine and Fuel System Repair*, 4th ed. Upper Saddle River, NJ: Prentice Hall, 1994.
- Espenschied, Roland F. *Diesel Engines.* Athens, GA: American Association for Vocational Instructional Materials, 1990.
- *Fundamentals of Service: Engines*, 7th ed. Moline, IL: Deere and Company, 1991.
- *Rebuild Manual, Cummins Diesel 10 Litre Engines.* Columbus, IN: Cummins Engine Co., 1984.
- *Series 60 Service Manual.* Detroit, MI: Detroit Diesel Corp., 1995.
- *Service Manual, 3176B Diesel Truck Engine.* Peoria, IL: Caterpillar, Inc., 1995.

Note: Engine service manuals can be ordered through the local dealership

Suggested Activities

Suggested Supplemental Resources

Electronic Media

- *Diesel Short Block Service* video (MER-5214-VW). Shows how to prepare a block before installing the main bearings, crankshaft, rod and piston assembly, and other components in a typical diesel short block. 1993.

- *Diesel Engine Reassembly* video (MER-5210-VW). Shows how to install the major parts of a diesel engine back onto its short block. 1993.

  The above are available from:

  NIMCO
  102 Hwy. 81 North
  P.O. Box 9
  Calhoun, KY 42327-0009
  Phone: 800-962-6662 or Fax: 502-273-5844
  http://www.nimcoinc.com

- *Cast Heads, Gaskets, and the Cylinder Block* (VH1-103PT), 10-minute videotape—Discusses common failures of the cylinder block and its components and how to prevent them. Available from:

  Dana Corporation
  Publication Services
  P.O. Box 453
  Toledo, OH 43692-0453
  Phone: 419-535-4285 or Fax: 419-535-4396

- *Diesel Engines/Mechanics Series*

  — *Camshaft and Cylinder Liners.* VHS, 12 minutes

  — *Internal Disassembly—Part One.* VHS, 11 minutes

  — *Internal Disassembly—Part Two.* VHS, 12 minutes

  — *Measurements and Evaluation.* VHS, 14 minutes

  These tapes are available singly or as part of multi-unit training modules from:

  Thomson Learning
  P.O. Box 6904
  Florence, KY 41022-6904
  Tel: 1-800-354-9706
  Email: esales@thomsonlearning.com

- *Diesel Engine Series*

— *Diesel Engine Teardown.* VHS, 25 minutes

— *Diesel Shortblock Service.* VHS, 24 minutes

These videotapes cover disassembly, inspection, and short block reassembly procedures on several different types of diesel engines. They are available singly or as part of a multi-tape training module from:

Echoscan, Inc.
2930 Pine Ave., Suite 5263
Niagara Falls, NY 14301
http://www.echoscaninc.com
E-mail: sales@echoscaninc.com

Written Test

Name ____

Date ______________________________ Score__________

Objective 1

Match terms related to a cylinder block with their definitions.

1. Counterbore
2. Crevice seal
3. Crocus cloth
4. Cylinder liner
5. Cylinder liner protrusion
6. Cylinder pack

_____ a. Removable sleeve inserted into the bore of an engine block and used as a load-bearing surface for the piston and rings

_____ b. Lip machined in the top of the block bore that forms a mechanical stop for the cylinder liner

_____ c. Distance the cylinder liner stands out above the block deck surface when installed

_____ d. One-cylinder kit consisting of liner, piston, and rings

_____ e. Flexible cloth impregnated with iron oxide particles that cleans metal surfaces without removing any material

_____ f. Lower water jacket seal between a wet cylinder liner and the crankcase

Objective 2

Distinguish between types of cylinder block cooling methods by placing an "A" by the statements about air cooled cylinder blocks and an "L" by the statements about liquid cooled cylinder blocks.

_____ a. Cylinder replacement is less costly.

_____ b. Cylinders are usually integral-bore design with cooling fins.

_____ c. Cooling jacket and coolant have been eliminated which reduces weight.

_____ d. Hot water is available for in-cab heating and defrosting.

_____ e. Engine noise is much greater due to lack of sound-absorbing cooling jacket.

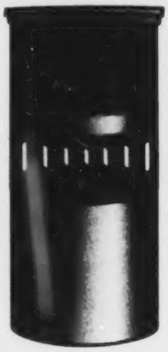
_____ f. Cylinders and heads must be kept clean to maximize heat transfer.

_____ g. Cooling jacket is used which adds weight, strength, and sound absorption.

Written Test

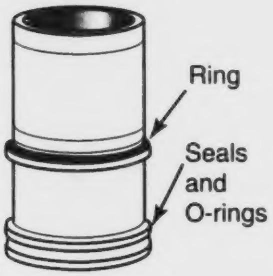
Objective 3

Identify the types of cylinder liners in the illustrations below. Write your answers in the blanks provided.



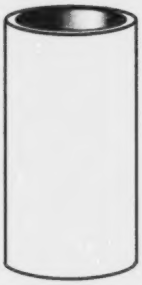
a. ______________________

____


Ring
Seals and O-rings

b. ______________________

____



c. ______________________

____

Objective 4

Match the types of cylinder liners with their characteristics.

1. Air-cooled sleeve
2. Combination wet/dry liner
3. Dry liner
4. Integral bore
5. Wet liner

_____ a. Piston and rings ride directly in the block; there is no sleeve.

_____ b. Coolant flows around the liner allowing direct heat transfer from the cylinder to the coolant. This results in better combustion control and greater efficiency.

_____ c. The upper half of the liner is directly cooled by liquid surrounding the liner. The lower half of the liner is cooled by water inside the cylinder block water jacket surrounding the liner.

_____ d. Top portion is covered with cooling fins that are exposed to air blown by the fan. Bottom portion is smooth and fits in cylinder block. This portion is surrounded by lubricant so it is cooled by the lubrication system.

_____ e. Individual cylinder liners are press-fit into machined cylinders in the cylinder block. The liner forms an inner bore to the existing cylinder and provides a wear surface for the piston and rings.

Objective 5

Complete statements concerning causes of abnormal sleeve wear by filling in the blanks with the correct answers.

a. Twisted o-ring seals cause ______________________________

____

b. Liner protrusion creates a weak ______________ seal at either that liner or an adjacent one.

c. Cavitation erosion

- Occurs when air bubbles in the coolant flow strike the ______________ removing small bits of material.
- Is caused by the depletion of ______________________________.

*Permission to duplicate this test is granted.

Answers to Written Test

Objective 1

a. 4
b. 1
c. 5
d. 6
e. 3
f. 2

Objective 2

a. L
b. A
c. A
d. L
e. A
f. A
g. L

Objective 3

a. Combination wet/dry liner
b. Wet liner
e. Dry liner

Objective 4

a. 4
b. 5
c. 2
d. 1
e. 3

Objective 5

a. Any of the following: Compression leakage, increased oil consumption, or blow-by
b. Head gasket
c. — Cylinder liner
— Supplemental coolant additives (SCAs)

Prerequisites:
1-A, 2-A, 1-B,
and 2-B

Learning Activities Sheet

Student Name ______________________________

Place a checkmark in the appropriate box as you complete each of the steps below.

☐ 1. **Take** Pretest provided by instructor. After test has been evaluated, follow instructor's recommendations.

☐ 2. **Read** Objective Sheet.

☐ 3. **Study** Information Sheet, Objectives 1 through 4.

☐ 4. **Observe** Demonstration of procedures to be used in completing Job Sheets 1 and 2.

☐ 5. **Do** Job Sheet 1, "Pressure Test a Cylinder Block" and Job Sheet 2, "Disassemble and Clean a Cylinder Block."

☐ 6. **Stop** After completing each job sheet, have your instructor evaluate your performance. If the evaluation is satisfactory, continue to the next job sheet. If the evaluation is not satisfactory, study the procedure outlined in that job sheet, and redo the job sheet. After satisfactorily completing Job Sheets 1 and 2, continue to step 7.

☐ 7. **Study** Information Sheet, Objective 5.

☐ 8. **Observe** Demonstration of procedures to be used in completing Job Sheet 3.

☐ 9. **Do** Job Sheet 3, "Inspect a Cylinder Block."

☐ 10. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 11. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 3 and repeat steps 7 through 10.

☐ 11. **Observe** Demonstration of procedures to be used in completing Job Sheets 4, 5, and 6.

☐ 12. **Do** Job Sheet 4, "Install New Camshaft Bushings," Job Sheet 5, "Clean and Inspect Cylinder Bores," and Job Sheet 6, "Install Cylinder Liners and Set Liner Protrusion."

☐ 13. **Stop** After completing each job sheet, have your instructor evaluate your performance. If the evaluation is satisfactory, continue to the next job sheet. If the evaluation is not satisfactory, study the procedure outlined in that job sheet, and redo the job sheet. After satisfactorily completing Job Sheets 4, 5, and 6, continue to step 14.

☐ 14. **Check** With instructor for any additional assignments to be completed.

☐ 15. **Do** Additional assignments listed below.

____

____

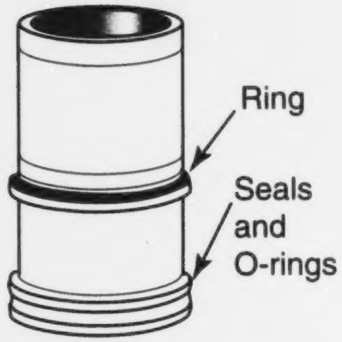
____

☐ 16. **Take** Posttest provided by instructor. After test has been evaluated, follow instructor's recommendations.

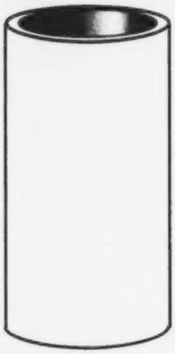
☐ 17. **Stop** Have instructor evaluate your unit performance. If the evaluation is satisfactory, proceed to next learning activities sheet. If evaluation is not satisfactory, ask instructor for further instructions.

***Permission to duplicate this form is granted.**

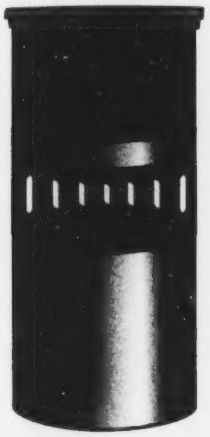
Types of Cylinder Liners


Ring
Seals and O-rings

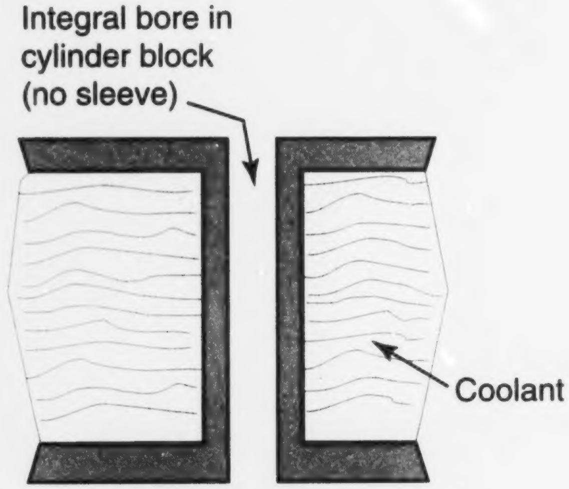
Wet liner



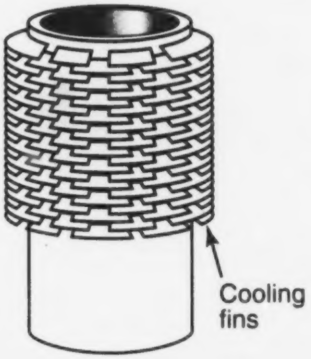
Dry liner



Combination wet-dry liner


Integral bore in cylinder block (no sleeve)
Coolant

Integral bore


Cooling fins

Air-cooled sleeve

Unit 4-B

Crankshafts and Bearings

Unit Contents

Teacher Page

Teacher Components

Suggested Activities 4B–3

Written Test 4B–9

Answers to Written Test 4B–17

Learning Activities Sheet 4B–19

Transparency Masters

1—Parts of a Crankshaft 4B–23
2—Crankshaft Throw Arrangements 4B–25
3—Parts of Main and Connecting Rod Bearings 4B–27
4—Special Design Features of Main Bearings 4B–29

Student Page

Student Components

Objective Sheet 4B–3

Information Sheet 4B–5

Job Sheets

1—Remove, Clean, and Inspect a Crankshaft 4B–15
2—Install Main Bearings and Crankshaft 4B–23
3—Perform an In-Frame Bearing Roll-In 4B–27
4—Inspect Viscous Vibration Damper/Harmonic Balancer 4B–33
5—Inspect Bonded Vibration Damper/Harmonic Balancer 4B–39
6—Inspect Flywheel 4B–43

Suggested Activities

Instructional Plan

Preparation

- Read the unit carefully and plan for instruction.
- Review "Teaching Suggestions." Plan for classroom activities.
- Plan your presentation to take advantage of student learning styles and to accommodate special-needs students.
- Prepare classroom. Put up posters and charts and display articles and other references related to this unit.
- Obtain films, videotapes, and other resources to supplement instruction of this unit. See "Resources Used in Developing This Unit" and "Suggested Supplemental Resources" for more information.
- For self-paced instruction, review Learning Activities Sheet. Modify as appropriate to include additional activities and/or resources available in your classroom. Make one copy for each student.
- Make transparencies from the transparency masters included in this unit. These appear in the teacher edition only.

Delivery and Application

Unit Introduction (self-paced instruction)

- Provide student with Learning Activities Sheet and unit of instruction.
- Review unit contents with student.
- Have the student complete the steps in the learning activities sheet.

Unit Introduction (group instruction)

- Provide students with unit of instruction.
- Discuss unit and specific objectives.
- Discuss the information sheet. Implement teaching plan to localize, supplement, and personalize the unit. Reinforce basic academic and workplace skills when applicable.

Suggested Activities

- Discuss and demonstrate the job sheets. Make sure all required tools, equipment, and materials are available. Review with students the criteria for evaluation of these activities and the rating scale that will be used to indicate job performance.

Teaching Suggestions

- Make a display of crankshafts and bearings, and have students identify their main components and features.
- Have students identify the different types of crankshaft throw arrangements using vehicles/equipment available in the shop.
- Demonstrate the three methods of balancing crankshafts as discussed in Objective 5—internal, external, and mechanical methods. Make sure that students can identify the different components involved in each method.
- Show samples of crankshafts that show excessive wear. Have students analyze and determine the root cause.
- Show examples of bearings that show excessive wear. Have students analyze and determine the root cause. Also discuss which characteristic of a good bearing (Objective 7) may have failed.
- Cut apart a main rod bearing or connecting rod bearing to show the layers of bearing materials as outlined in Objective 8. Also have students identify the main components of these bearings.
- Discuss the most common problems that you have encountered with crankshafts and bearings. Describe what may be required to solve each problem.

Evaluation

- Make copies of the written test. Add or modify test items as needed. The written test serves as both a pretest and posttest to assist in measuring each student's competency gains.
- Give and evaluate pretest. Modify lesson plan to include additional instruction for those areas where students were deficient.
- Evaluate the job sheets. When the student is ready to perform a specific task, obtain a copy of the job sheet which may be found in the student edition. Then observe the student performing the procedure.

Process evaluation—Place a mark in the box to the left of each designated checkpoint if the student has satisfactorily completed the process step(s) for each checkpoint area. If the student is unable to complete the procedure correctly, have the student review the materials and try again.

Product evaluation—Once the student has satisfactorily completed the procedure, rate the student product (outcome) using the criteria that are provided as part of the job sheet. If the student's product is unacceptable, have the student review the materials and submit another product for evaluation.

Two sample performance evaluation keys have been provided below. Many other keys are available. Select one rating (grading scale) that best fits your program needs.

Sample A

4—**Skilled**—Can perform job with no additional training.
3—**Moderately skilled**—Has performed job during training program; limited additional training may be required.
2—**Limited skill**—Has performed job during training program; additional training is required to develop skill.
1—**Unskilled**—Is familiar with process, but is unable to perform job.
0—**No exposure**—No information or practice provided during training program.

Sample B

Yes—Can perform job with no additional training.
No—Is unable to perform job satisfactorily.

- Give and evaluate the posttest.
- Meet individually with students to evaluate their progress through this unit of instruction and indicate to them possible areas of improvement.
- Reteach and retest as required.

Resources Used in Developing This Unit

Print Media

- Clark, Elton, et al. *Diesel Fundamentals*. Stillwater, OK: Mid-America Vocational Curriculum Consortium, Inc., 1988.
- Dagel, John F. *Diesel Engine and Fuel System Repair*, 4th ed. Upper Saddle River, NJ: Prentice Hall, 1994.
- Espenschied, Roland F. *Diesel Engines*. Athens, GA: American Association for Vocational Instructional Materials, 1990.
- *Fundamentals of Service: Engines*, 7th ed. Moline, IL: Deere and Company, 1991.

Suggested Activities

- *Rebuild Manual, Cummins Diesel 10 Litre Engines*. Columbus, IN: Cummins Engine Co., 1984.
- *Series 60 Service Manual*. Detroit, MI: Detroit Diesel Corp., 1995.
- *Service Manual, 3176B Diesel Truck Engine*. Peoria, IL: Caterpillar, Inc., 1995.

Note: Engine service manuals can be ordered through the local dealership

Suggested Supplemental Resources

Print Media

- *Crankshaft Failure Analysis* (SEBV0548), 12-page book. (1988)
- *Shaft Failure Analysis* (SEBV0565), 24-page book. (1991)
- *Engine Bearing Failure Analysis* (SEBV0544), 20-page book. (1988)
- *Anti-friction Bearing Failure Analysis* (SEBV0562), 24-page book. (1988)

The 4 titles listed above are available from your local CAT dealer or write the following for more information:

Caterpillar Service Training
600 W. Washington St., Bldg. JJ
East Peoria, IL 61630

- *Failure Analysis–Bearings*. (985573). Available as booklet or slide set.
- *Sealing Failures–Causes and Cures*. (3387169). Available as booklet, slide set, or audio tape.
- *Capscrew Torque and Preload*. (3387304). Available as booklet, slide set, or audio tape.
- *Capscrew Torque Plus Angle*. (3387560-63). Available as booklet, slide set, audio tape, as as well as VHS videotape.

The 4 titles listed above are available from your local Cummins Engine Company dealer/distributor or call:

Cummins Engine Company Customer Relations
800-345-5654 or 502-453-8549 or for more information call 1-800-DIESELS

- *Engine Bearing Failure Analysis Service Manual.* (21-1.2) Available from:

  Mack Trucks, Inc.
  2100 Mack Boulevard
  P.O. Box M
  Allentown, PA 18105-5000
  610-439-3011

- *ASE Test Prep Series*—Medium/Heavy Duty Truck, 2nd ed. (Diesel Engines). Albany, NY: Delmar Publishers, 2002.

  Also available in CD ROM format

- Bennett, Sean. *Medium/Heav Duty Truck Engines, Fuel and Computerized Management Systems.* Albany, NY: Delmar Publishers, 1999.

- Bennett, Sean. *Today's Technician: Medium/Heavy Duty Truck Diesel Engines.* Albany, NY: Delmar Publishers, 2001.

- Brady, Robert. *Diesel Engine and Fuel System Repair*, 5th ed. Upper Saddle River, NJ: Prentice Hall Inc., 2002.

Electronic Media

- *The Bearings* (VH1-104PT), 8-minute videotape—Examines common problems of the connecting rod and main bearings, crankshaft, and the oil pump. Available from:

  Dana Corporation
  Publication Services
  P.O. Box 453
  Toledo, OH 43692-0453
  Phone: 419-535-4285 or Fax: 419-535-4396

- *FOS Bearings and Seals* set of 118 slides. Available from:

  Deere & Company
  Distribution Service Center
  P.O. Box 186
  Moline, IL 61266-1086
  800-522-7448

- *Diesel Short Block Service*, VHS, 24 minutes.

  Illustrates how to prep a block before installing the main bearings, crankshaft, rod and pistons assembly and other components in a typical diesel short block.

Suggested Activities

- Diesel Engine Teardown, VHS, 25 minutes

  Details the steps needed to disassemble, inspect, and measure the parts of diesel engines.

  The videos listed above are available from:

  Nimco
  P.O. Box 9
  102 Hwy. 81 N.
  Calhoun, KY 42327-0009
  1-800-962-6662
  www.nimcoinc.com

Written Test

Name ______________________________

Date ______________________________ Score __________

Objective 1

Match terms related to crankshafts and bearings with their definitions. Write the correct numbers in the blanks. Definitions continue on the next page.

1. Bearing
2. Bearing cap
3. Bushing
4. Companion cylinders
5. Connecting rod
6. Connecting rod bearing
7. Crankshaft
8. Crankshaft web
9. Crush
10. Dynamically balanced
11. End play
12. Fillet
13. Journal
14. Main bearing
15. Overload
16. Spread
17. Statically balanced
18. Thrust bearings
19. Wear

_____ a. In balance at operating speeds

_____ b. Full-round sleeve used to support light loads

_____ c. Part of a shaft that revolves in a bearing

_____ d. In balance at rest

_____ e. Bearing that is used to support the crankshaft in the cylinder block

_____ f. Pistons that move up and down at the same time

_____ g. Half-round sleeve used to support heavy loads

_____ h. Curved joint between the journal and web that adds strength

_____ i. Non-machined area between the rod journal and the main journal

_____ j. Structural member that transfers the force from the piston to the crankpin

_____ k. Bearing load in excess of the load the bearing was designed to carry

_____ l. Possible forward and backward (axial) movement of the crankshaft in the main bearing bore or connecting rods on the crankpin

_____ m. Circumferential interference fit necessary to hold two bearing halves securely in the housing bore

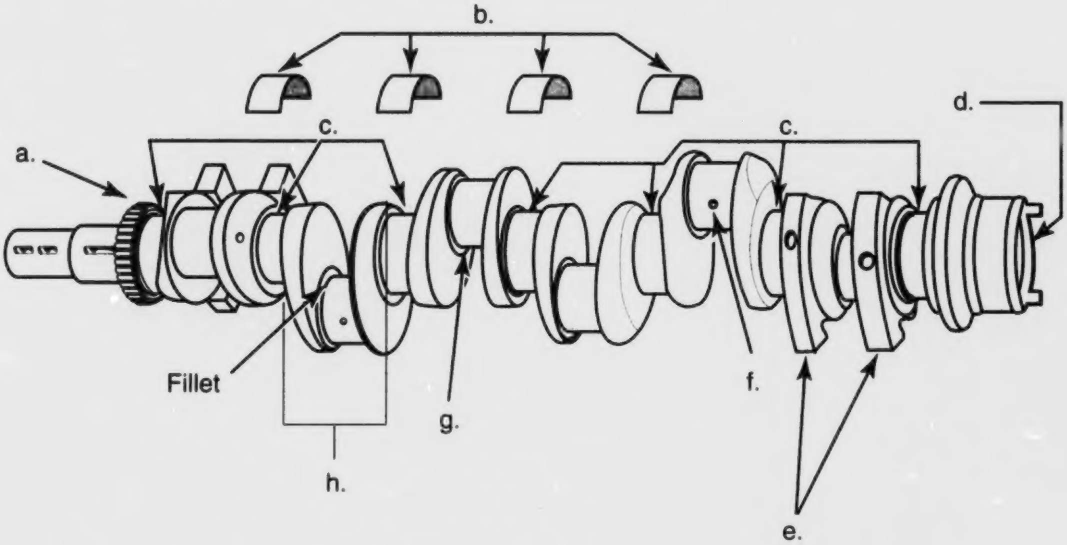
Written Test

_____ n. Bearing at the big end of the connecting rod in which the crankpin rotates

_____ o. Excess of diameter at the outside parting edges in the free state over the housing bore into which the bearing is to be installed

Objective 2

Identify the parts of a crankshaft shown below. Write your answers in the blanks provided.



a. ____________________ b. ____________________

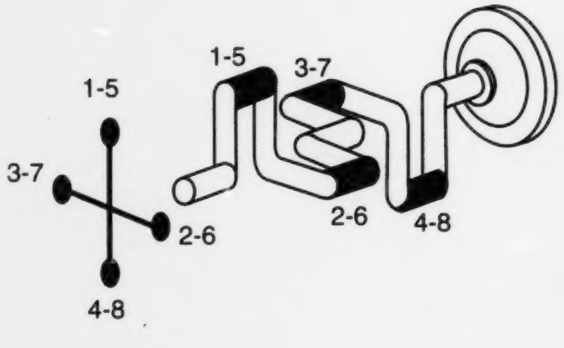
c. ____________________ d. ____________________

e. ____________________ f. ____________________

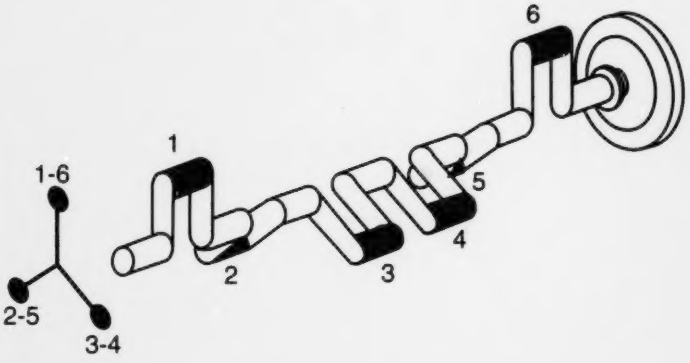
g. ____________________ h. ____________________

Objective 3

Identify the engine design according to the crankshaft throws shown. Write your answers in the blanks provided.



a. ______________________________



b. ______________________________

Objective 4

Select true statements concerning crankshaft throw characteristics by writing "T" for true or "F" for false in the space provided next to each statement.

_____ a. Crankshaft throw arrangement has no effect on vibration levels during engine operation.

_____ b. Crankshaft throw arrangement determines firing order.

_____ c. Inline engines having odd numbers of cylinders have matched throws.

_____ d. V-type engines typically have two pistons sharing one crankpin.

Written Test

Objective 5

Describe two methods of balancing a crankshaft by stating the method and then explaining what is involved.

a. ____________________ method

____

____

____

b. ____________________ method

____

____

____

Objective 6

Complete statements concerning crankshaft lubrication by filling in the blanks with the correct answers.

a. Crankshaft main journals are fed pressurized oil directly from the ______________________________.

b. Each connecting rod journal is cross-drilled to receive pressurized oil from ______________________________.

Objective 7

Match the characteristics of a good bearing with their descriptions. Write the correct numbers in the blanks.

1. Conformability
2. Corrosion resistance
3. Embedability
4. Seizure resistance (load-carrying capacity)
5. Temperature strength
6. Wear rate

_____ a. Ability to adequately support the crankshaft, yet not cause wear to the crankshaft journals

_____ b. Ability to maintain smooth operation at high engine temperatures

_____ c. Ability to remain unaffected by the acids that form in the lubricating oil

_____ d. Ability to absorb small particles of dirt, metal, or carbon into the bearing material without causing serious bearing damage

_____ e. Ability to adapt to the shape of the crankshaft journal

_____ f. Ability to maintain smooth motion during high-pressure loading from combustion forces

Objective 8

Distinguish among bearing materials by placing the following letters next to the correct characteristics:

- B—Backing
- F—Flashing
- L—Lining
- O—Overplating

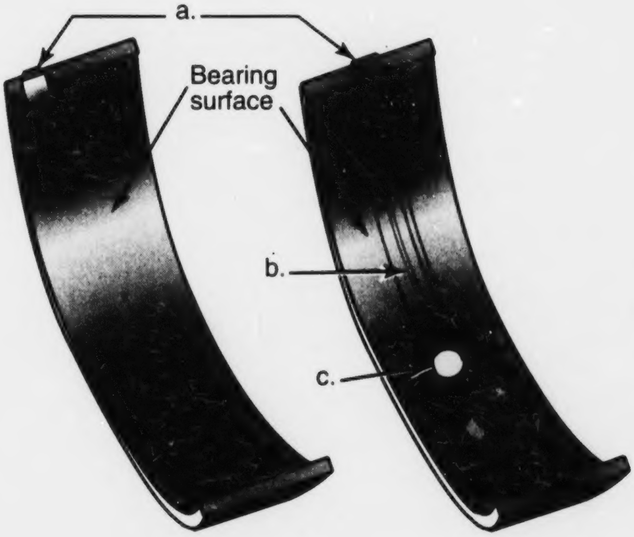
_____ a. Made of tin plating; allows quick seating of the crankshaft journals and protects bearing prior to installation

_____ b. Made of alloys of aluminum, copper, lead, and tin; provides the load-bearing wear surface

_____ c. Made of steel; provides strength for bearing lining

Objective 9

Identify the parts of main and connecting rod bearings shown below. Write your answers in the blanks provided.



a. ____

b. ____

c. ____

Written Test

Objective 10

Distinguish among special design features of main bearings by placing the following letters next to the correct characteristics:

- C—Crush
- L—Bearing locating device
- O—Oil holes and grooves
- S—Spread

_____ a. The outside diameter of the bearing shell is slightly larger than the inside diameter of the housing bore. This gives a snap-fit.

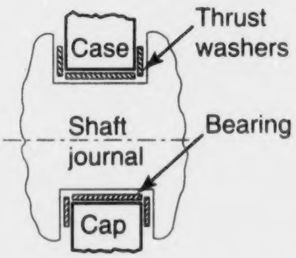
_____ b. The parting face of the bearing shell protrudes slightly above the parting face of the bearing saddle. The bearing shell is pressed into the bearing housing, preventing any shell movement.

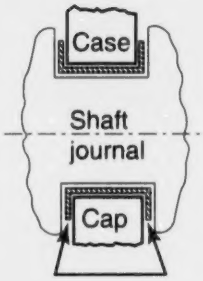
_____ c. Used to keep bearing from rotating or shifting in their housings; include lugs, tangs, and dowels

_____ d. Used to provide lubrication to bearing surfaces

Objective 11

Identify the types of thrust bearings in the illustrations below.





a. ____________________ b. ____________________

Objective 12

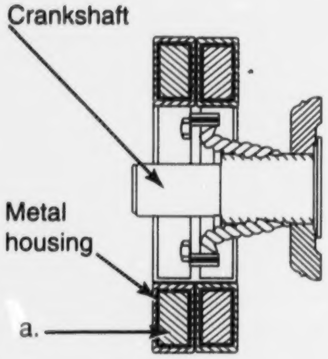
Describe two symptoms of bearing failure.

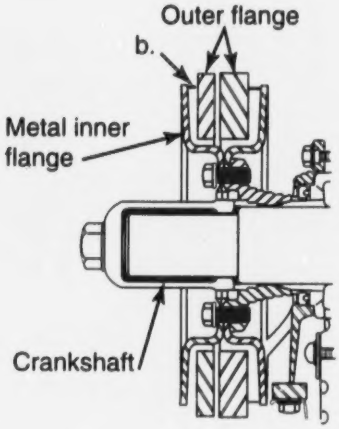
a. ____

b. ____

Objective 13

Distinguish between the types of vibration dampers by placing an "X" under the illustration of a bonded (rubber element) type.


Crankshaft
Metal housing
a.


Outer flange
b.
Metal inner flange
Crankshaft

a. ____________________ b. ____________________

Objective 14

Select from the following list the correct functions of a flywheel by placing an "X" in the appropriate blanks

_____ a. Prevents crush

_____ b. Stores momentum

_____ c. Smoothes out piston power pulses

_____ d. Prevents spread

_____ e. Provides friction surface for clutch disc

***Permission to duplicate this test is granted.**

Answers to Written Test

Objective 1

a. 10
b. 3
c. 13
d. 17
e. 14
f. 4
g. 1
h. 12
i. 8
j. 5
k. 15
l. 11
m. 9
n. 6
o. 16

Objective 2

a. Crankshaft gear
b. Upper bearing halves
c. Main bearing journals
d. Flywheel hub or flange
e. Counterweights
f. Oil hole
g. Connecting rod journal (crankpin)
h. Crankshaft throw

Objective 3

a. V-type (V-8)
b. In-line (In-line 6)

Objective 4

a. F
b. T
c. F
d. T

Objective 5

Any two of the following:

a. Internal method
  - Counterweights—Add weight to balance out the weight of the piston and rod
  - Balance holes—Precision drilled to remove weight and to dynamically balance the crankshaft

b. External method
  - Vibration damper—Absorbs torsional vibrations produced by the firing pulses of each piston; also known as a harmonic balancer.
  - Flywheel—Weights cast or welded to one side help offset the internal weight of the pistons and rods.

c. Mechanical method—Internal balance shafts
  - Gear driven by crankshaft to rotate at twice crankshaft speed.
  - Timed so that weight moves in opposite direction of piston—as piston moves up, weight moves down; as piston moves down, weight moves up
  - Opposing motion cancels out the vibration created by the reciprocating weight of the piston and rod.

Answers to Written Test

Objective 6

a. Main oil gallery
b. An adjacent main journal

Objective 7

a. 6
b. 5
c. 2
d. 3
e. 1
f. 4

Objective 8

a. F
b. L
c. B

Objective 9

a. Locating tangs/lugs
b. Oil groove
c. Oil hole (or slot)

Objective 10

a. S
b. C
c. L
d. O

Objective 11

a. Separate
b. Flanged

Objective 12

Any two of the following:

a. Decreasing oil pressure as engine reaches operating temperature
b. Metallic particles in oil
c. Excessive oil consumption
d. Sharp, rhythmic, metallic knocking noise

Objective 13

b

Objective 14

b, c, e

Prerequisites:
None

Learning Activities Sheet

Student Name ______________________________

Place a checkmark in the appropriate box as you complete each of the steps below.

☐ 1. **Take** Pretest provided by instructor. After test has been evaluated, follow instructor's recommendations.

☐ 2. **Read** Objective Sheet.

☐ 3. **Study** Information Sheet, Objectives 1 through 6.

☐ 4. **Observe** Demonstration of procedures to be used in completing Job Sheet 1.

☐ 5. **Do** Job Sheet 1, "Remove, Clean, and Inspect a Crankshaft."

☐ 6. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 7. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 1 and repeat steps 4 through 6.

☐ 7. **Study** Information Sheet, Objectives 7 through 12.

Optional

☐ 8. **View** Videotape entitled "The Bearings", and slide set entitled "FOS-Bearings and Seals".

☐ 9. **Observe** Demonstration of procedures to be used in completing Job Sheet 2.

☐ 10. **Do** Job Sheet 2, "Install Main Bearings and Crankshaft."

☐ 11. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 12. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 2 and repeat steps 9 through 11.

Learning Activities Sheet

☐ 12. **Observe** Demonstration of procedures to be used in completing Job Sheet 3.

☐ 13. **Do** Job Sheet 3, "Perform an In-Frame Bearing Roll-In."

☐ 14. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 15. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 3 and repeat steps 7, and 12 through 14.

☐ 15. **Study** Information Sheet, Objective 13.

☐ 16. **Observe** Demonstration of procedures to be used in completing Job Sheet 4.

☐ 17. **Do** Job Sheet 4, "Inspect Viscous Vibration Damper/Harmonic Balancer."

☐ 18. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 19. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 4 and repeat steps 15 through 18.

☐ 19. **Observe** Demonstration of procedures to be used in completing Job Sheet 5.

☐ 20. **Do** Job Sheet 5, "Inspect Bonded Vibration Damper/Harmonic Balancer."

☐ 21. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 22. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 5 and repeat steps 15, and 19 through 21.

☐ 22. **Study** Information Sheet, Objective 14.

☐ 23. **Observe** Demonstration of procedures to be used in completing Job Sheet 6.

☐ 24. **Do** Job Sheet 6, "Inspect Flywheel."

☐ 25. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 26. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 6 and repeat steps 22 through 25.

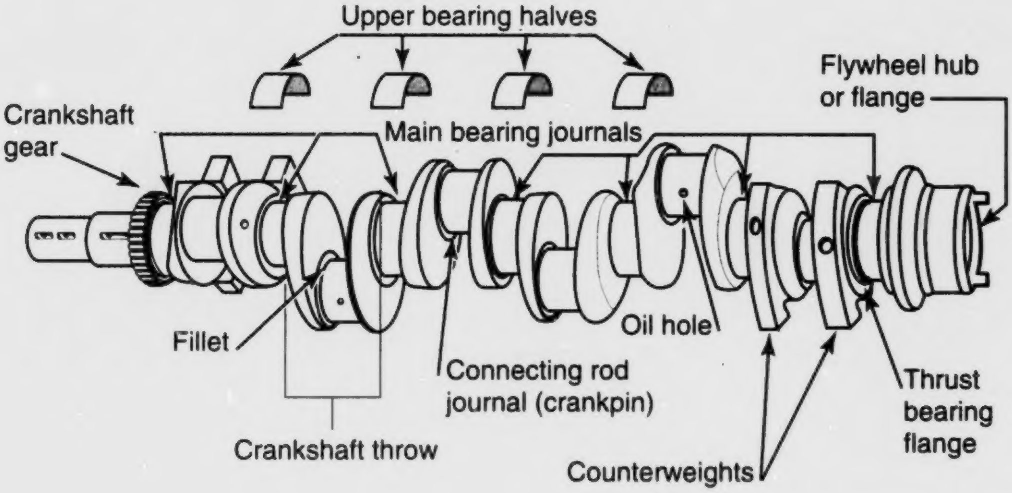
☐ 26. **Check** With instructor for any additional assignments to be completed.

☐ 27. **Take** Posttest provided by instructor. After test has been evaluated, follow instructor's recommendations.

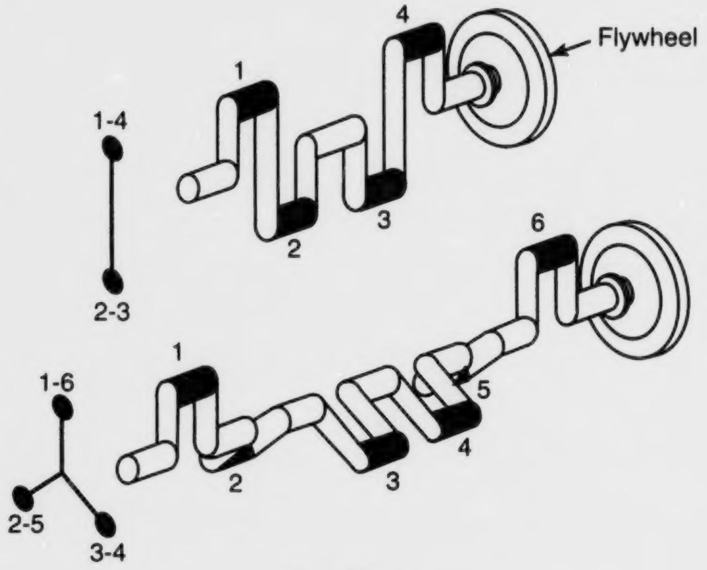
☐ 28. **Stop** Have instructor evaluate your unit performance. If the evaluation is satisfactory, proceed to next learning activities sheet. If evaluation is not satisfactory, ask instructor for further instructions.

***Permission to duplicate this form is granted.**

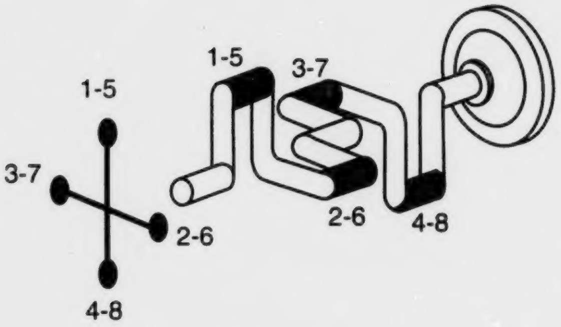
Parts of a Crankshaft


Upper bearing halves
Flywheel hub or flange
Crankshaft gear
Main bearing journals
Fillet
Oil hole
Connecting rod journal (crankpin)
Thrust bearing flange
Crankshaft throw
Counterweights

Crankshaft Throw Arrangements


4
Flywheel
1
1-4
3
2
2-3
6
1
1-6
5
4
2
3
2-5
3-4

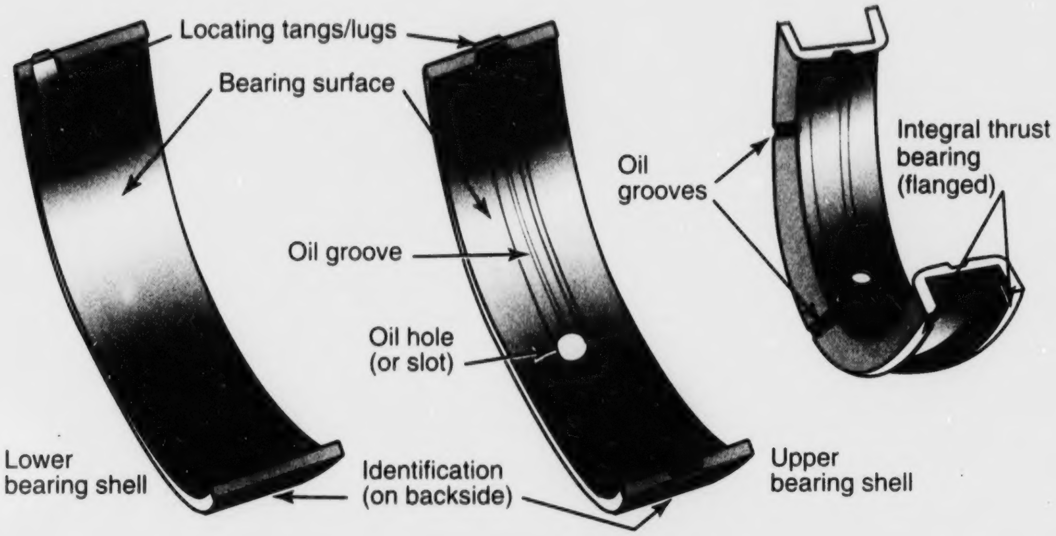
In-line


1-5
3-7
1-5
3-7
2-6
2-6
4-8
4-8

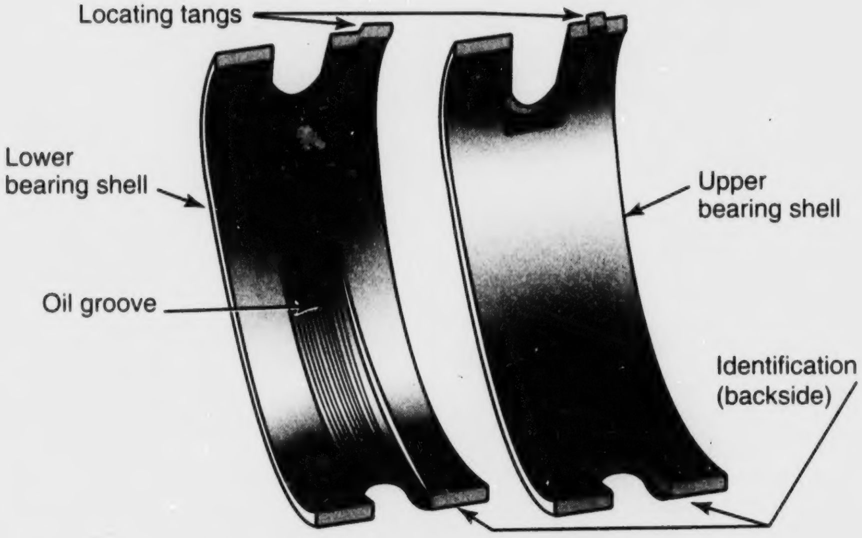
V-type

Reproduced by permission of John Deere Publishing, Deere & Company, Moline, IL. Engines © 1991. All rights reserved.

Parts of Main and Connecting Rod Bearings

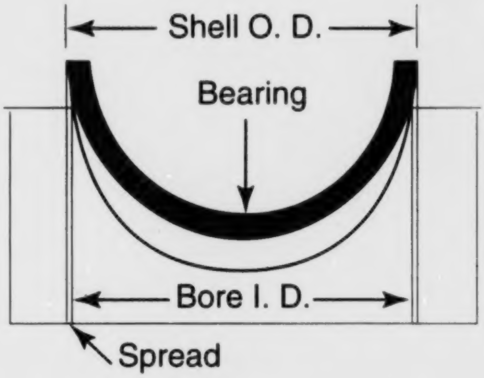

Locating tangs/lugs
Bearing surface
Oil grooves
Integral thrust bearing (flanged)
Oil groove
Oil hole (or slot)
Lower bearing shell
Identification (on backside)
Upper bearing shell

Main Rod Bearings

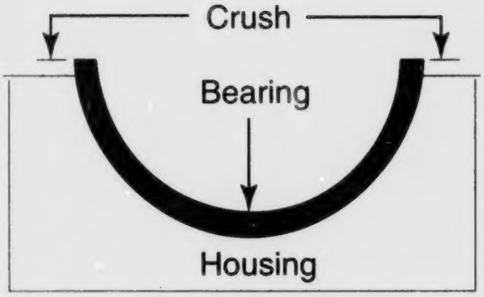

Locating tangs
Lower bearing shell
Upper bearing shell
Oil groove
Identification (backside)

Connecting Rod Bearings

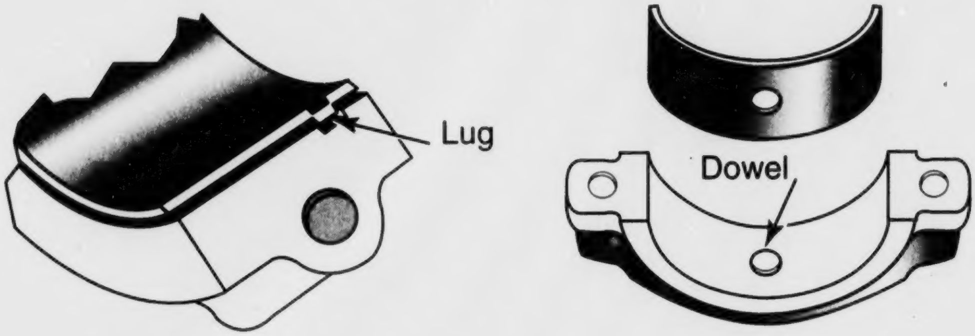
Special Design Features of Main Bearings


Shell O. D.
Bearing
Bore I. D.
Spread

Spread


Crush
Bearing
Housing

Crush



Bearing Locating Devices

Unit 5-B Pistons and Connecting Rods

Unit Contents

Teacher Components

Teacher Page

Suggested Activities 5B–3

Written Test 5B–9

Answers to Written Test 5B–17

Learning Activities Sheet 5B–19

Transparency Masters

- 1—Piston and Connecting Rod Assembly 5B–21
- 2—Parts of a Piston 5B–23
- 3—Common Piston Designs 5B–25
- 4—Piston Ring Designs 5B–27
- 5—Parts of a Connecting Rod 5B–29

Student Components

Student Page

Objective Sheet 5B–3

Information Sheet 5B–5

Job Sheets

- 1—Remove, Disassemble, and Inspect a Piston and Connecting Rod Assembly 5B–15
- 2—Measure Piston-to-Cylinder Wall Clearance and Ring End Gap 5B–23
- 3—Assemble and Install Piston and Connecting Rod Assembly . . . 5B–27

Suggested Activities

Instructional Plan

Preparation

- Read the unit carefully and plan for instruction.
- Review "Teaching Suggestions." Plan for classroom activities.
- Plan your presentation to take advantage of student learning styles and to accommodate special-needs students.
- Prepare classroom. Put up posters and charts and display articles and other references related to this unit.
- Obtain films, videotapes, and other resources to supplement instruction of this unit. See "Resources Used in Developing This Unit" and "Suggested Supplemental Resources" for more information.
- For self-paced instruction, review Learning Activities Sheet. Modify as appropriate to include additional activities and/or resources available in your classroom. Make one copy for each student.
- Make transparencies from the transparency masters included in this unit. These appear in the teacher edition only.

Delivery and Application

Unit Introduction (self-paced instruction)

- Provide student with Learning Activities Sheet and unit of instruction.
- Review unit contents with student.
- Have the student complete the steps in the learning activities sheet.

Unit Introduction (group instruction)

- Provide students with unit of instruction.
- Discuss unit and specific objectives.
- Discuss the information sheet. Implement teaching plan to localize, supplement, and personalize the unit. Reinforce basic academic and workplace skills when applicable.

Suggested Activities

- Discuss and demonstrate the job sheets. Make sure all required tools, equipment, and materials are available. Review with students the criteria for evaluation of these activities and the rating scale that will be used to indicate job performance.

Teaching Suggestions

- Disassemble (or have students disassemble) a piston and connecting rod assembly, and have students identify the primary components. Have students practice assembling the components so they can see how they fit together. Also discuss their functions.

- Make a display of as many different pistons as possible, especially showing different ring grooves and crowns. Discuss with students why there are so many variations.

- Make a display of the different types of piston rings. Discuss their similarities and how easy it is to confuse them. Also discuss their functions. Then demonstrate the correct procedure for installing them.

- Show examples of piston ring end gaps and piston ring designs. Discuss how students will know which designs to use.

- Lay out a disassembled connecting rod, and have students identify the parts and then reassemble.

- Show samples of pistons that show excessive wear. Have students analyze and determine the root cause.

- Discuss the most common problems that you have encountered with pistons and connecting rods. Describe what may be required to solve each problem.

Evaluation

- Make copies of the written test. Add or modify test items as needed. The written test serves as both a pretest and posttest to assist in measuring each student's competency gains.

- Give and evaluate pretest. Modify lesson plan to include additional instruction for those areas where students were deficient.

- Evaluate the job sheets. When the student is ready to perform a specific task, obtain a copy of the job sheet which may be found in the student edition. Then observe the student performing the procedure.

Suggested Activities

Process evaluation—Place a mark in the box to the left of each designated checkpoint if the student has satisfactorily completed the process step(s) for each checkpoint area. If the student is unable to complete the procedure correctly, have the student review the materials and try again.

Product evaluation—Once the student has satisfactorily completed the procedure, rate the student product (outcome) using the criteria that are provided as part of the job sheet. If the student's product is unacceptable, have the student review the materials and submit another product for evaluation.

Two sample performance evaluation keys have been provided below. Many other keys are available. Select one rating (grading scale) that best fits your program needs.

Sample A

4—**Skilled**—Can perform job with no additional training.
3—**Moderately skilled**—Has performed job during training program; limited additional training may be required.
2—**Limited skill**—Has performed job during training program; additional training is required to develop skill.
1—**Unskilled**—Is familiar with process, but is unable to perform job.
0—**No exposure**—No information or practice provided during training program.

Sample B

Yes—Can perform job with no additional training.
No—Is unable to perform job satisfactorily.

- Give and evaluate the posttest.
- Meet individually with students to evaluate their progress through this unit of instruction and indicate to them possible areas of improvement.
- Reteach and retest as required.

Resources Used in Developing This Unit

Print Media

- Clark, Elton, et al. *Diesel Fundamentals.* Stillwater, OK: Mid-America Vocational Curriculum Consortium, Inc., 1988.
- Dagel, John F. *Diesel Engine and Fuel System Repair*, 3rd ed. Upper Saddle River, NJ: Prentice Hall, 1994.
- Espenschied, Roland F. *Diesel Engines.* Athens, GA: American Association for Vocational Instructional Materials, 1990.
- *Fundamentals of Service: Engines*, 7th ed. Moline, IL: Deere and Company, 1991.

Suggested Activities

- *Rebuild Manual, Cummins Diesel 10 Litre Engines.* Columbus, IN: Cummins Engine Co., 1984.
- *Series 60 Service Manual.* Detroit, MI: Detroit Diesel Corp., 1995.
- *Service Manual, 3176B Diesel Truck Engine.* Peoria, IL: Caterpillar, Inc., 1995.

Note: Engine service manuals can be ordered through the local dealership.

Suggested Supplemental Resources

Print Media

- *Piston, Ring, and Liner Failure Analysis* (SEBV0553), 17-page book. (1988).
- *Connecting Rod Failure Analysis* (SEBV0546), 17-page book. (1988)

The above are available from your local CAT dealer or write the following for more information:

Caterpillar Service Training
600 W. Washington St., Bldg. JJ
East Peoria, IL 61630

- *Failure Analysis–Pistons and Liners.* (985579). Available as booklet or slide set. Available from your local Cummins Engine Company dealer/distributor or call:

Cummins Engine Company Customer Relations
800-345-5654 or 502-453-8549 or for more information call 1-800-DIESELS

- *Failure Analysis of Pistons, Rings, Liners, and Sleeves Service Manual.* (21-1)
- *E6-4VH Piston Failure Analysis Service Manual.* (21-1A)

The above are available from:

Mack Trucks, Inc.
2100 Mack Boulevard
P.O. Box M
Allentown, PA 18105-5000
610-439-3011

- *ASE Test Prep Series*—Medium/Heavy Duty Truck, 2nd ed. (Diesel Engines). Albany, NY: Delmar Publishers, 2002.

Also available in CD ROM format

- Bennett, Sean. *Medium/Heav Duty Truck Engines, Fuel and Computerized Management Systems.* Albany, NY: Delmar Publishers, 1999.
- Bennett, Sean. *Today's Technician: Medium/Heavy Duty Truck Diesel Engines.* Albany, NY: Delmar Publishers, 2001.
- Brady, Robert. *Diesel Engine and Fuel System Repair*, 5th ed. Upper Saddle River, NJ: Prentice Hall Inc., 2002.

Electronic Media

- *Diesel Short Block Service*, VHS, 24 minutes.

  Illustrates how to prep a block before installing the main bearings, crankshaft, rod and pistons assembly and other components in a typical diesel short block.

- Diesel Engine Teardown, VHS, 25 minutes

  Details the steps needed to disassemble, inspect, and measure the parts of diesel engines.

  The videos listed above are available from:

  Nimco
  P.O. Box 9
  102 Hwy. 81 N.
  Calhoun, KY 42327-0009
  1-800-962-6662
  www.nimcoinc.com

Written Test

Name ____________________

Date ____________________ Score __________

Objective 1

Match terms related to pistons and connecting rods with their definitions. Write the correct numbers in the blanks provided.

1. Blow-by
2. Cam-ground
3. Match marks
4. Piston ring end gap
5. Piston ring lands
6. Piston pin boss

_____ a. Piston area that forms a wall between the ring grooves

_____ b. Machining the piston slightly oval in shape to allow for uneven expansion

_____ c. Combustion gases that leak past the rings into the crankcase.

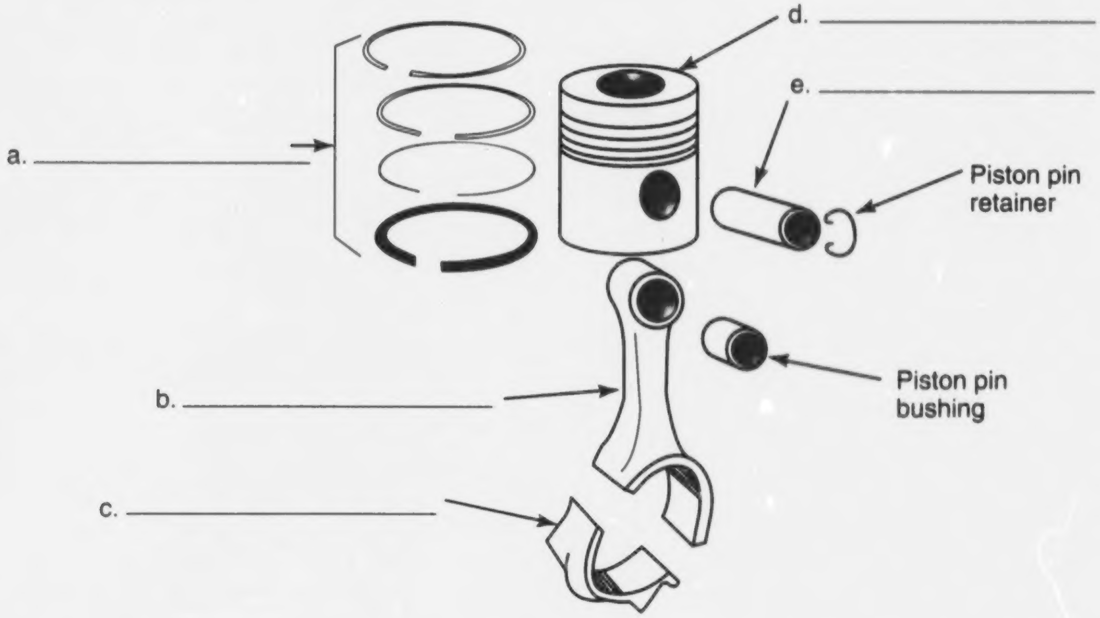
_____ d. Reinforced area on both sides of the piston that supports the piston pin

_____ e. Identifying marks on the connecting rod and cap that allow them to be reassembled exactly as manufactured

Written Test

Objective 2

Label the primary components of a piston and connecting rod assembly. Write your answers in the blanks provided.



Objective 3

Match piston and connecting rod components with their correct functions. Write the correct numbers on the blanks provided.

1. Piston crown
2. Piston pin
3. Piston pin bushing
4. Piston pin retainer
5. Piston rings
6. Connecting rod
7. Connecting rod cap

_____ a. Holds the lower half of the bearing shell

_____ b. Provides a replaceable wear surface for the piston pin

_____ c. Joins piston to crankshaft and transmits force and motion

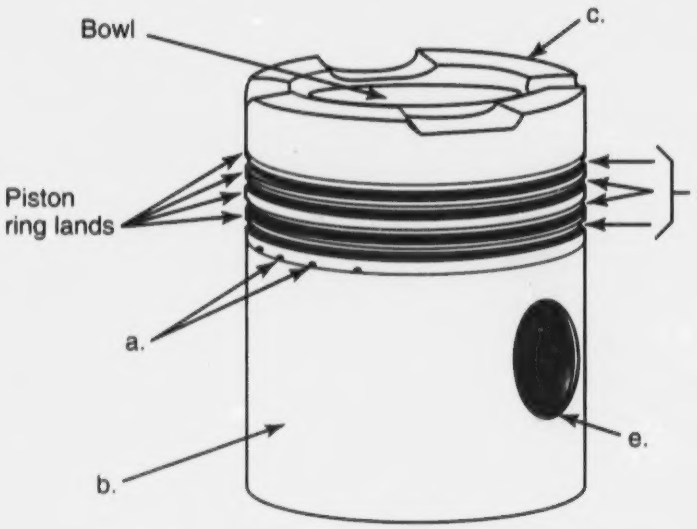
_____ d. Provides pivot point for the connecting rod

_____ e. Locks the piston pin in place; can be spring steel clips or Teflon® end plug

_____ f. Seal the cylinder above the piston

Objective 4

Identify parts of a piston shown below. Write your answers in the blanks provided.



a. ______________________ d. ______________________

b. ______________________ e. ______________________

c. ______________________

Objective 5

Match piston parts with their correct functions. Write the correct numbers on the blanks provided.

1. Bowl
2. Oil holes
3. Piston crown
4. Piston pin bore
5. Piston ring grooves
6. Piston ring lands
7. Piston skirt

_____ a. Receives the force of combustion

_____ b. Concave area in the crown that forms part of the combustion chamber

_____ c. Allow oil to escape after the oil control rings wipe it off the cylinder wall

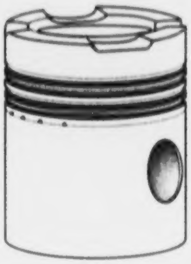
_____ d. Guides the piston inside the cylinder, prevents cocking, and minimizes side wear

_____ e. Receives connecting rod end and piston pin to form assembly

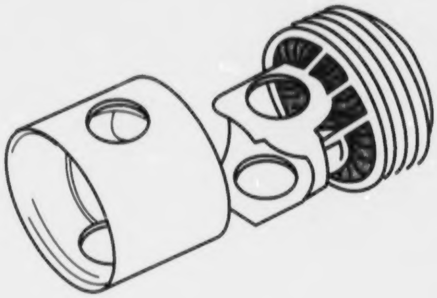
Written Test

Objective 6

Distinguish between common piston designs by placing an "X" next to the illustration of a multi-piece design.



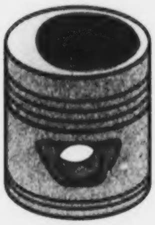
a. ______________________



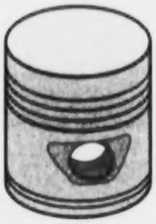
b. ______________________

Objective 7

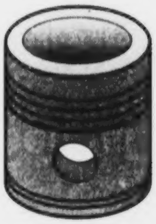
Identify the types of piston crown designs (heads) shown below. Write your answers in the blanks provided.



a. ________________



b. ________________



c. ________________

Objective 8

Distinguish among the types of piston rings by placing the following letters next to the correct descriptions:

- I—Intermediate compression rings
- O—Oil control rings
- T—Top compression rings

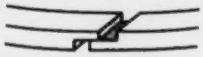
_____ a. Provide a strong secondary gas seal to help contain combustion gases

_____ b. Prevent excess oil from flooding the combustion chamber

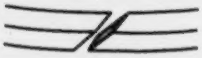
_____ c. Seal the cylinder above the piston, preventing hot gases from leaking into the crankcase

Objective 9

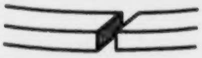
Identify the common types of piston ring end gaps shown below. Write your answers in the blanks provided.



a. ____________________



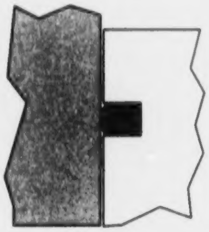
b. ____________________



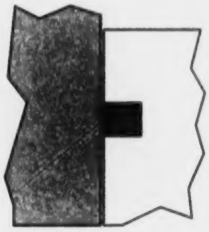
c. ____________________

Objective 10

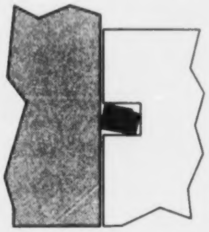
Identify the following piston ring designs. Write your answers in the blanks provided.



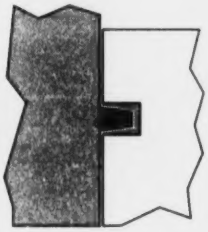
a. ____________________________



b. ____________________________



c. ____________________________



d. ____________________________

Objective 11

Match the piston ring designs with their correct characteristics. Write your answers in the blanks provided.

1. Barrel-faced ring
2. Inside bevel ring
3. Keystone ring
4. Rectangular ring
5. Taper-faced ring

_____ a. Designed to cock inside the ring groove during the downstroke; generally used as intermediate ring

_____ b. Quick-seating ring with excellent blow-by control; commonly used as a top compression ring

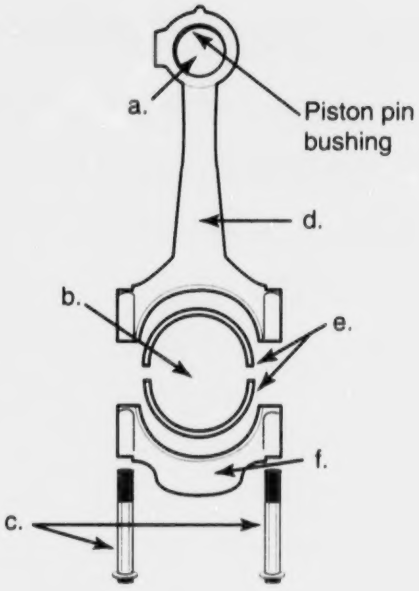
_____ c. Common ring design that distributes sealing pressure along the entire face of the ring; typically used as a top compression ring

_____ d. Uses tapered sides to improve sealing and minimize sticking

Written Test

Objective 12

Identify the parts of a connecting rod in the illustration below. Write your answers in the blanks provided.



a. ______________________ d. ______________________

b. ______________________ e. ______________________

c. ______________________ f. ______________________

Objective 13

Match the connecting rod components with their correct descriptions. Write our answes in the blanks provided.

1. Bearing inserts
2. Bolts
3. Connecting rod cap
4. Crankshaft pin bore
5. Piston pin bore
6. Shank

_____ a. Forged as one piece with the connecting rod, then machined and cut; matched to each rod

_____ b. Body of the rod, usually having an I-beam cross-section

_____ c. Replaceable load-bearing wear surfaces for the crankshaft rod journals

_____ d. Little end of the rod that is machined to hold the piston pin bushing

_____ e. Big end of the rod that is machined to hold the crankshaft bearing insert

Objective 14

Describe at least two causes for the following types of abnormal piston wear.

a. Scoring

- ____
- ____

b. Corrosion

- ____
- ____

Objective 15

List five possible causes of high oil consumption and blow-by.

a. ____

b. ____

c. ____

d. ____

e. ____

***Permission to duplicate this test is granted.**

Answers to Written Test

Objective 1

a. 5
b. 2
c. 1
d. 6
e. 3

Objective 2

a. Piston rings
b. Connecting rod
c. Connecting rod cap
d. Piston
e. Piston pin

Objective 3

a. 7
b. 3
c. 6
d. 2
e. 4
f. 5

Objective 4

a. Oil holes
b. Piston skirt
c. Piston crown
d. Piston ring grooves
e. Piston pin bore

Objective 5

a. 3
b. 1
c. 2
d. 7
e. 4

Objective 6

b

Objective 7

a. Irregular head
b. Flat head
c. Concave head

Objective 8

a. I
b. O
c. T

Answers to Written Test

Objective 9

a. Step
b. Angle
c. Butt

Objective 10

a. Barrel-faced ring
b. Rectangular ring
c. Inside bevel ring
d. Keystone ring

Objective 11

a. 2
b. 1
c. 4
d. 3

Objective 12

a. Piston pin bore
b. Crankshaft pin bore
c. Bolts
d. Shank (of connecting rod)
e. Bearing inserts
f. Connecting rod cap

Objective 13

a. 3
b. 6
c. 1
d. 5
e. 4

Objective 14

a. Scoring: Any two of the following:
- Grit in engine oil or fuel
- Dust from unfiltered intake air
- Carbon particles form the combustion chamber
- Insufficient warm-up
- Inadequate lubrication
- Inadequate cooling
- Lugging/overloading

b. Corrosion: Any two of the following:
- Water leaking into the cylinder
- Low engine operating temperature
- Incorrect engine oil
- Acids from condensation/combustion forming in the lubricating oil

Objective 15

Any five of the following:
a. Worn rings
b. Excess piston-to-cylinder wall clearance
c. Rings installed incorrectly
d. Broken rings
e. Stuck rings
f. Slots in the oil control ring clogged
g. Mechanical damage to piston or cylinder wall
h. Worn connecting rod bearings
i. Missing/leaking piston pin retainers

Prerequisites:
None

Learning Activities Sheet

Student Name ______________________________

Place a checkmark in the appropriate box as you complete each of the steps below.

☐ 1. **Take** Pretest provided by instructor. After test has been evaluated, follow instructor's recommendations.

☐ 2. **Read** Objective Sheet.

☐ 3. **Study** Information Sheet, Objectives 1 through 8.

Optional

☐ 4. **View** Videotapes entitled "Diesel Engine Teardown" and "Diesel Shortblock Service."

☐ 5. **Observe** Demonstration of procedures to be used in completing Job Sheet 1.

☐ 6. **Do** Job Sheet 1, "Remove, Disassemble, and Inspect a Piston and Connecting Rod Assembly."

☐ 7. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to Step 8. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 1 and repeat steps 5 through 7.

☐ 8. **Study** Information Sheet, Objectives 9 through 11.

☐ 9. **Observe** Demonstration of procedures to be used in completing Job Sheet 2.

☐ 10. **Do** Job Sheet 2, "Measure Piston-to-Cylinder Wall Clearance and Ring End Gap."

☐ 11. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to Step 12. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 2 and repeat steps 9 through 11.

☐ 12. **Study** Information Sheet, Objectives 12 through 15.

Learning Activities Sheet

☐ 13. **Observe** Demonstration of procedures to be used in completing Job Sheet 3.

☐ 14. **Do** Job Sheet 3, "Assemble and Install Piston and Connecting Rod Assembly."

☐ 15. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to Step 16. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 3 and repeat steps 13 through 15.

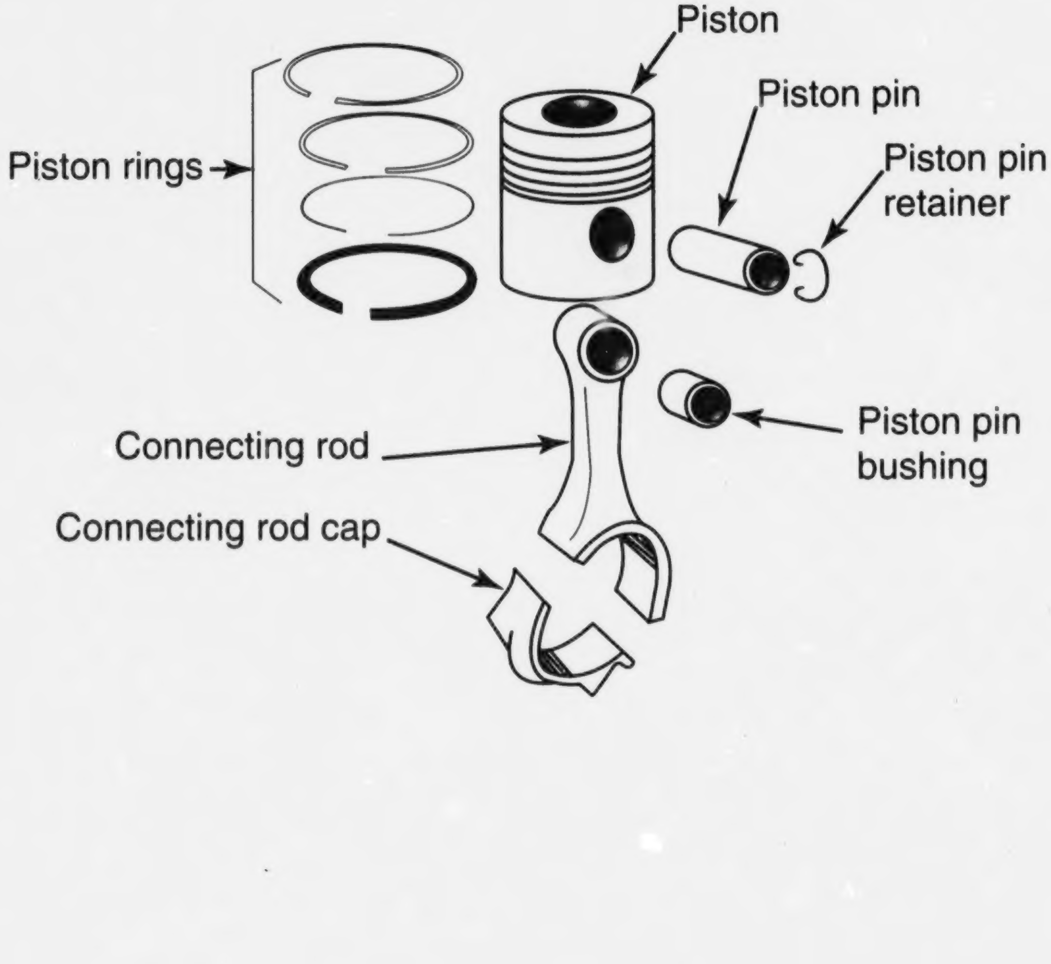
☐ 16. **Check** With instructor for any additional assignments to be completed.

☐ 17. **Take** Posttest provided by instructor. After test has been evaluated, follow instructor's recommendations.

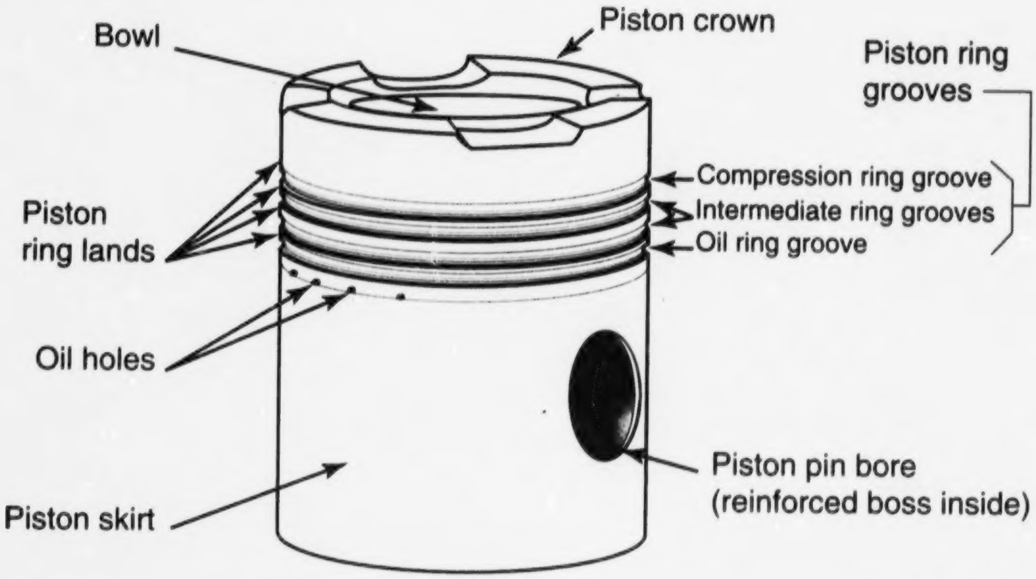
☐ 18. **Stop** Have instructor evaluate your unit performance. If the evaluation is satisfactory, proceed to next learning activities sheet. If evaluation is not satisfactory, ask instructor for further instructions.

***Permission to duplicate this form is granted.**

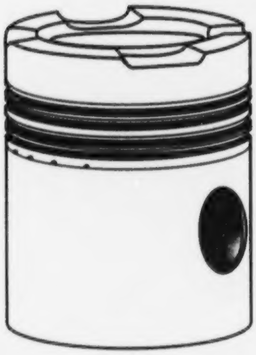
Piston and Connecting Rod Assembly


Piston
Piston pin
Piston pin retainer
Piston rings
Connecting rod
Piston pin bushing
Connecting rod cap

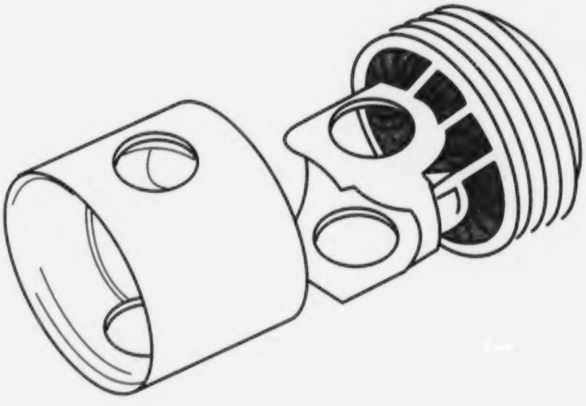
Parts of a Piston


Piston crown
Bowl
Piston ring grooves
Compression ring groove
Intermediate ring grooves
Oil ring groove
Piston ring lands
Oil holes
Piston pin bore (reinforced boss inside)
Piston skirt

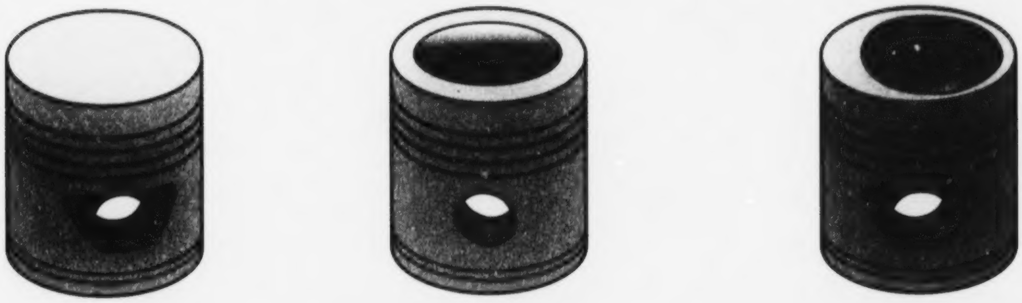
Common Piston Designs



Single piece
(truck-type)



Multi-piece (articulated
or cross-head type)



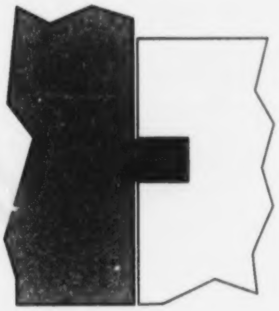
Flat head

Concave head

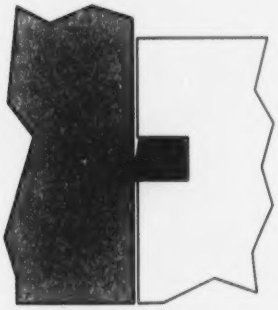
Irregular head

Piston Crowns

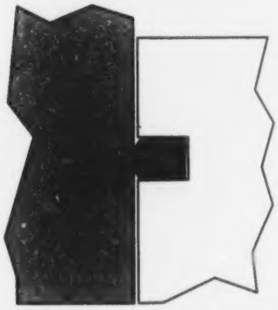
Piston Ring Designs



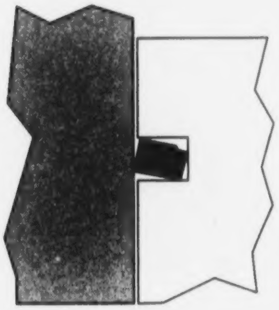
Rectangular ring



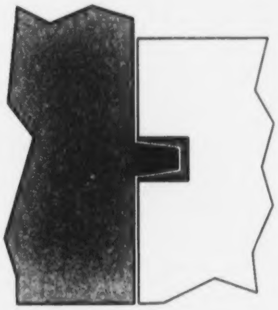
Taper-faced ring



Barrel-faced ring

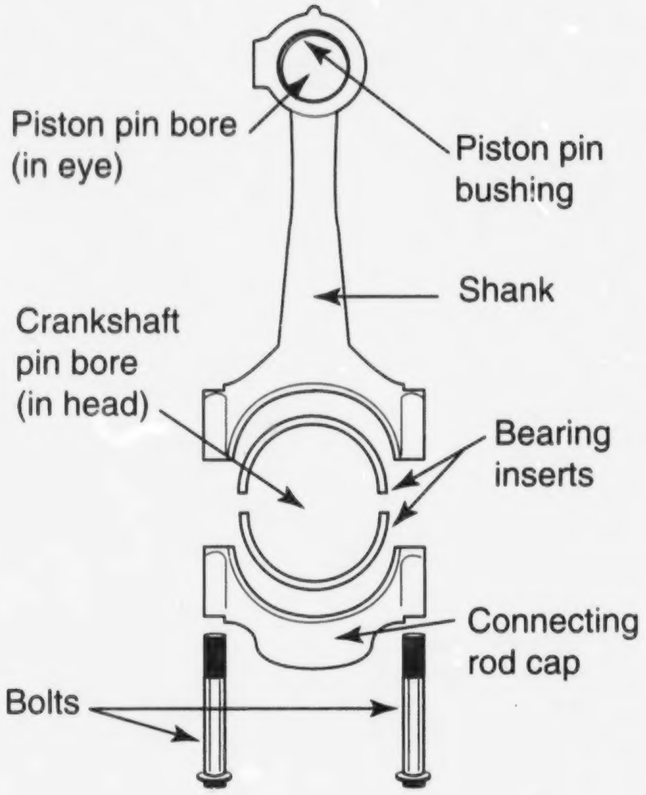


Inside bevel ring



Keystone ring

Parts of a Connecting Rod


Piston pin bore
(in eye)
Piston pin
bushing
Shank
Crankshaft
pin bore
(in head)
Bearing
inserts
Connecting
rod cap
Bolts

Camshafts, Trains, and Timing

Unit Contents

Teacher Components

Teacher Page

Suggested Activities 6B-3
Written Test 6B-7
Answers to Written Test 6B-13
Learning Activities Sheet 6B-15

Transparency Masters

1—Parts of a Cam Lobe 6B-17
2—Parts of a Valve Train 6B-19
3—Typical Gear Train Components 6B-21

Student Components

Student Page

Objective Sheet 6B-3
Information Sheet 6B-5

Job Sheets

1—Remove, Clean, and Inspect a Camshaft 6B-13
2—Remove, Inspect, and Install Cam Bushings 6B-17
3—Install a Camshaft and Set Cam Timing 6B-21

Suggested Activities

Instructional Plan

Preparation

- Read the unit carefully and plan for instruction.
- Review "Teaching Suggestions." Plan for classroom activities.
- Plan your presentation to take advantage of student learning styles and to accommodate special-needs students.
- Prepare classroom. Put up posters and charts and display articles and other references related to this unit.
- Obtain films, videotapes, and other resources to supplement instruction of this unit. See "Resources Used in Developing This Unit" and "Suggested Supplemental Resources" for more information.
- For self-paced instruction, review Learning Activities Sheet. Modify as appropriate to include additional activities and/or resources available in your classroom. Make one copy for each student.
- Make transparencies from the transparency masters included in this unit. These appear in the teacher edition only.

Delivery and Application

Unit Introduction (self-paced instruction)

- Provide student with Learning Activities Sheet and unit of instruction.
- Review unit contents with student.
- Have the student complete the steps in the learning activities sheet.

Unit Introduction (group instruction)

- Provide students with unit of instruction.
- Discuss unit and specific objectives.
- Discuss the information sheet. Implement teaching plan to localize, supplement, and personalize the unit. Reinforce basic academic and workplace skills when applicable.
- Discuss and demonstrate the job sheets. Make sure all required tools, equipment, and materials are available. Review with students the criteria for evaluation of these activities and the rating scale that will be used to indicate job performance.

Suggested Activities

Teaching Suggestions

- Discuss the different types of camshafts, and point out the advantages and disadvantages of each type and the most common applications of the two types.
- Have students identify the parts of a cam lobe using vehicles/equipment available in the shop. Discuss the importance of these parts.
- Use an actual vehicle available in the shop or a mock-up to show the basic operation of a valve train, as well as valve actuation and valve timing.
- Show examples of the different types of cam followers and lifters. Discuss their different applications and maintenance required.
- Have students identify the three basic methods of driving the camshaft (belt, chain, and gear) on actual vehicles/equipment available in the shop. Discuss their different applications and maintenance required.
- Construct a mock-up of a gear train, and discuss with students the basic components, operation, and the importance of gear timing.

Evaluation

- Make copies of the written test. Add or modify test items as needed. The written test serves as both a pretest and posttest to assist in measuring each student's competency gains.
- Give and evaluate pretest. Modify lesson plan to include additional instruction for those areas where students were deficient.
- Evaluate the job sheets. When the student is ready to perform a specific task, obtain a copy of the job sheet which may be found in the student edition. Then observe the student performing the procedure.

  Process evaluation—Place a mark in the box to the left of each designated checkpoint if the student has satisfactorily completed the process step(s) for each checkpoint area. If the student is unable to complete the procedure correctly, have the student review the materials and try again.

  Product evaluation—Once the student has satisfactorily completed the procedure, rate the student product (outcome) using the criteria that are provided as part of the job sheet. If the student's product is unacceptable, have the student review the materials and submit another product for evaluation.

  Two sample performance evaluation keys have been provided below. Many other keys are available. Select one rating (grading scale) that best fits your program needs.

Suggested Activities

Sample A

4—**Skilled**—Can perform job with no additional training.
3—**Moderately skilled**—Has performed job during training program; limited additional training may be required.
2—**Limited skill**—Has performed job during training program; additional training is required to develop skill.
1—**Unskilled**—Is familiar with process, but is unable to perform job.
0—**No exposure**—No information or practice provided during training program.

Sample B

Yes—Can perform job with no additional training.
No—Is unable to perform job satisfactorily.

- Give and evaluate the posttest.
- Meet individually with students to evaluate their progress through this unit of instruction and indicate to them possible areas of improvement.
- Reteach and retest as required.

Resources Used in Developing This Unit

Print Media

- Clark, Elton, et al. *Diesel Fundamentals*. Stillwater, OK: Mid-America Vocational Curriculum Consortium, Inc., 1988.
- Dagel, John F. *Diesel Engine and Fuel System Repair*, 4th ed. Upper Saddle River, NJ: Prentice Hall, 1994.
- Espenschied, Roland F. *Diesel Engines*. Athens, GA: American Association for Vocational Instructional Materials, 1990.
- *Fundamentals of Service: Engine*, 7th ed. Moline, IL: Deere and Company, 1991.
- *Rebuild Manual, Cummins Diesel 10 Litre Engines*. Columbus, IN: Cummins Engine Co., 1984.
- *Series 60 Service Manual*. Detroit, MI: Detroit Diesel Corp., 1995.
- *Service Manual, 3176B Diesel Truck Engine*. Peoria, IL: Caterpillar, Inc., 1995.

Note: Engine service manuals can be ordered through the local dealership

Suggested Supplemental Resources

Print Media

- *Engine Valve Failure Analysis* (SEBV0551), 14-page book. (1988).
- *Gear Failure Analysis* (SEBV0561), 24-page book. (1990).

The above are available from your local CAT dealer or write the following for more information.

Suggested Activities

Caterpillar Service Training
600 W. Washington St., Bldg. JJ
East Peoria, IL 61630

- *ASE Test Prep Series*—Medium/Heavy Duty Truck, 2nd ed. (Diesel Engines). Albany, NY: Delmar Publishers, 2002.

  Also available in CD ROM format

- Bennett, Sean. *Medium/Heav Duty Truck Engines, Fuel and Computerized Management Systems.* Albany, NY: Delmar Publishers, 1999.

- Bennett, Sean. *Today's Technician: Medium/Heavy Duty Truck Diesel Engines.* Albany, NY: Delmar Publishers, 2001.

- Brady, Robert. *Diesel Engine and Fuel System Repair*, 5th ed. Upper Saddle River, NJ: Prentice Hall Inc., 2002.

Electronic Media

- *The Valve Train and Timing Components* (VH1-102PT), 12-minute videotape—Examines common problems and failures in the valve train and timing components and how to prevent them. Available from:

  Dana Corporation
  Publication Services
  P.O. Box 453
  Toledo, OH 43692-0453
  Phone: 419-535-4285 or Fax: 419-535-4396

- Diesel Engine Teardown, VHS, 25 minutes

  Details the steps needed to disassemble, inspect, and measure the parts of diesel engines.

  The videos listed above are available from:

  Nimco
  P.O. Box 9
  102 Hwy. 81 N.
  Calhoun, KY 42327-0009
  1-800-962-6662
  www.nimcoinc.com

Written Test

Name ______________________________

Date ______________________ Score __________

Objective 1

Match terms related to camshafts, trains, and timing with their definitions. Write the correct numbers in the blanks.

1. Backlash
2. Cam follower
3. Cam lobe
4. Duration
5. Overlap
6. Train
7. Valve clearance
8. Valve crosshead

_____ a. Distance between the cam lobe and other valve train components

_____ b. Amount of time (in crankshaft degrees) that both valves are open

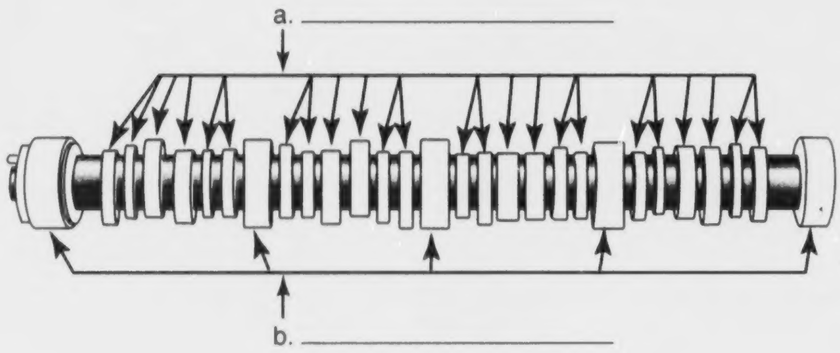
_____ c. Amount of time (in crankshaft degrees) that the valve is open

_____ d. Bridge-like component located between the rocker arm and valves that allows one cam lobe to open two valves simultaneously

_____ e. Oval-shaped, machined part of the camshaft that opens the valve

Objective 2

Label the primary parts of a camshaft. Write your answers in the blanks provided.



Written Test

Objective 3

Distinguish between the types of camshafts by placing an "X" next to the description of the camshaft used on a diesel engine with mechanical or electronic fuel injectors:

_____ a. Has one lobe per cylinder

_____ b. Has two lobes per cylinder

_____ c. Has three lobes per cylinder

Objective 4

Complete statements concerning the operation of a camshaft by circling the correct answers.

a. **(Valve train, Gear train)** is driven by the camshaft.

b. **(Valve train, Gear train)** is driven by the crankshaft.

c. **(Valve train, Gear train)** is a series of gears that transfer motion from crankshaft to camshaft.

d. **(Valve train, Gear train)** includes components that open and close the valves (intake and exhaust).

Objective 5

Match the parts of a cam lobe with their correct definitions. Write the correct answers in the blanks provided.

1. Base circle
2. Nose
3. Ramp flank
4. Valve lift

_____ a. Projection on the cam that determines how far the valve will open

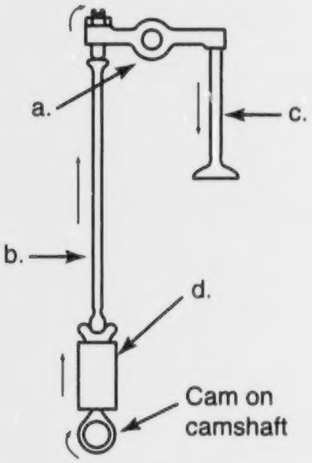
_____ b. Camshaft diameter at the lobe

_____ c. Contour on each side of the nose that determines how quickly the valve opens and closes

_____ d. Contour that determines how long the valve remains open at maximum lift

Objective 6

Identify the parts of a valve train. Write your answers in the blanks provided.



a. ______________________ c. ______________________

b. ______________________ d. ______________________

Objective 7

Complete statements concerning valve actuation by filling in the blanks with the correct answers.

a. For a cam in block design, the camshaft is mounted in the ______________________.

b. For a cam in head design, the camshaft is mounted in the ______________________.

c. Push rods are not used in the cam in ______________________ design.

Objective 8

Distinguish between two-stroke and four-stroke valve timing by placing a "2" next to the descriptions of a two-stroke cycle diesel engine and a "4" next to four-stroke.

_____ a. Camshaft turns at one-half speed of the crankshaft.

_____ b. Camshaft turns at the same speed as crankshaft.

_____ c. Exhaust valve is opened and closed once during one revolution of the crankshaft.

_____ d. Each intake and exhaust valve is opened and closed once during two revolutions of the crankshaft.

Written Test

Objective 9

Describe two types of camshaft bushings and how their fits are different.

a. ____

b. ____

Objective 10

Distinguish between types of cam followers and lifters by placing an "H" next to the description(s) of a hydraulic lifter and an "S" next to description(s) of a solid lifter:

_____ a. Requires periodic adjustment

_____ b. Lifter base is ground slightly convex, causing the lifter to rotate in its bore during valve opening; this evenly distributes wear across the cam and lifter contact surface.

_____ c. Uses engine oil pressure to pump up an internal plunger, maintaining zero valve clearance

_____ d. Typically used in light- or medium-duty applications

Objective 11

Match methods of driving the camshaft with their descriptions. Write the correct answers in the blanks provided. Answers may be used more than once.

1. Belt
2. Chain
3. Gear

_____ a. Most accurate method; no timing variations due to stretch

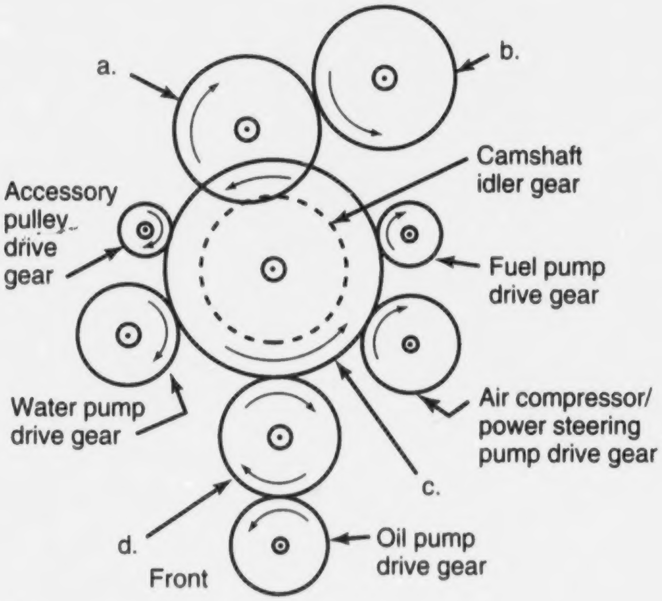
_____ b. Most efficient means of power transmission available; more noise

_____ c. Little noise or vibration; recommended replacement every 60,000 to 75,000 miles

_____ d. Longest service life with high friction loss and noise

Objective 12

Identify the components in a typical gear train. Write your answers in the blanks provided.


a.
b.
Camshaft idler gear
Accessory pulley drive gear
Fuel pump drive gear
Water pump drive gear
Air compressor/ power steering pump drive gear
c.
d.
Front
Oil pump drive gear

Courtesy of Detroit Diesel Corporation

a. ______________________ c. ______________________

b. ______________________ d. ______________________

Objective 13

Complete statements concerning gear timing by filling in the blanks with the correct answers.

a. Gear teeth are marked with ______________________, which are matched up during assembly.

b. Timing mark alignment synchronizes camshaft and ______________________.

c. Because of the different reduction ratios between the gears, some engines take many ______________________ to line up all the timing marks again.

d. A typical gear that is marked to ensure correct valve timing is the ______________________ gear.

***Permission to duplicate this test is granted.**

Answers to Written Test

Objective 1	a. 7 b. 5 c. 4 d. 8 e. 3
Objective 2	a. Cam lobes b. Bearing journals
Objective 3	c
Objective 4	a. Valve train b. Gear train c. Gear train d. Valve train
Objective 5	a. 4 b. 1 c. 3 d. 2
Objective 6	a. Rocker arm b. Push rod c. Valve d. Cam follower (valve lifter)
Objective 7	a. Cylinder block b. Cylinder head c. Head
Objective 8	a. 4 b. 2 c. 2 d. 4
Objective 9	a. One piece—Press-fit design e. Two-piece—Snap-fit in the bearing saddles

Answers to Written Test

Objective 10

a. S
b. S
c. H
d. H

Objective 11

a. 3
b. 2
c. 1
d. 3

Objective 12

a. Adjustable idler gear
b. Camshaft drive gear
c. Bull gear
d. Crankshaft timing gear

Objective 13

a. Any one answer: Dots, lines, or arrows
b. Crankshaft
c. Revolutions
d. Any one answer: Crankshaft, camshaft, or idler

Prerequisites:
None

Learning Activities Sheet

Student Name ______________________________

Place a checkmark in the appropriate box as you complete each of the steps below.

☐ 1. **Take** Pretest provided by instructor. After test has been evaluated, follow instructor's recommendations.

☐ 2. **Read** Objective Sheet.

☐ 3. **Study** Information Sheet, Objectives 1 through 8.

☐ 4. **Observe** Demonstration of procedures to be used in completing Job Sheet 1.

☐ 5. **Do** Job Sheet 1, "Remove, Clean, and Inspect a Camshaft."

☐ 6. **Stop** Ask instructor to evaluate your performance and if the evaluation is satisfactory, continue to step 7. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 1 and repeat steps 3 through 6.

☐ 7. **Study** Information Sheet, Objectives 9 and 10.

☐ 8. **Observe** Demonstration of procedures to be used in completing Job Sheet 2.

☐ 9. **Do** Job Sheet 2, "Remove, Inspect, and Install Cam Bushings."

☐ 10. **Stop** Ask instructor to evaluate your performance and if the evaluation is satisfactory, continue to step 11. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 2 and repeat steps 7 through 10.

☐ 11. **Study** Information Sheet, Objectives 11 through 13.

Optional

☐ 12. **View** Videotape entitled "The Valve Train and Timing Components".

Learning Activities Sheet

☐ 13. **Observe** Demonstration of procedures to be used in completing Job Sheet 3.

☐ 14. **Do** Job Sheet 3, "Install a Camshaft and Set Cam Timing."

☐ 15. **Stop** Ask instructor to evaluate your performance and if the evaluation is satisfactory, continue to step 16. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 3 and repeat steps 11, and 13 through 15.

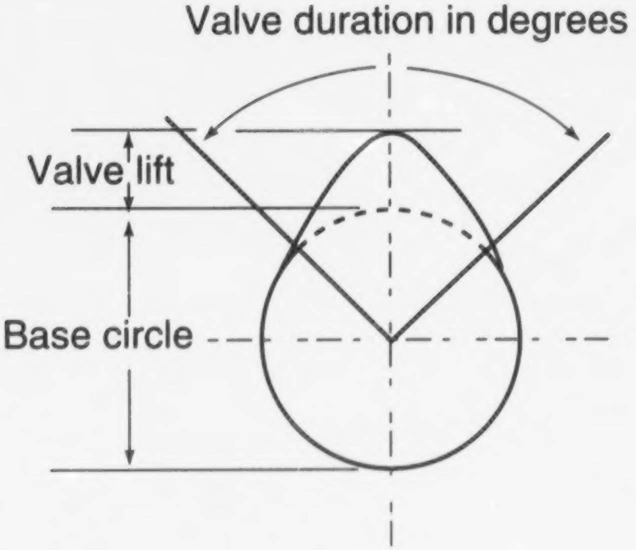
☐ 16. **Check** With instructor for any additional assignments to be completed.

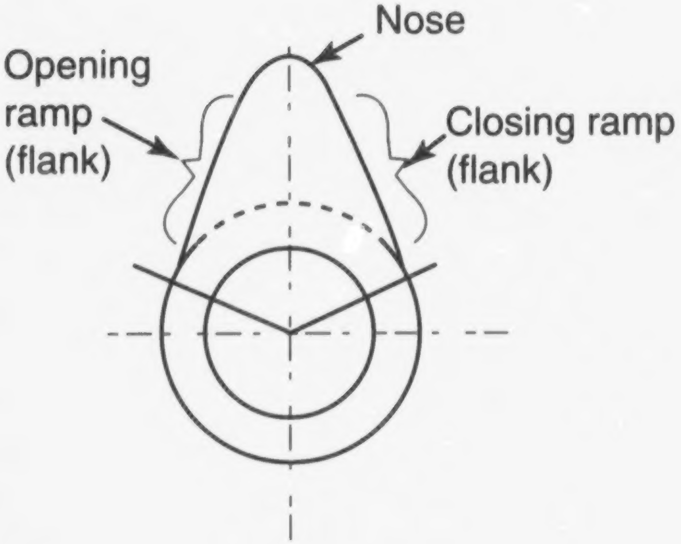
☐ 17. **Take** Posttest provided by instructor. After test has been evaluated, follow instructor's recommendations.

☐ 18. **Stop** Have instructor evaluate your unit performance. If the evaluation is satisfactory, proceed to next learning activities sheet. If evaluation is not satisfactory, ask instructor for further instructions.

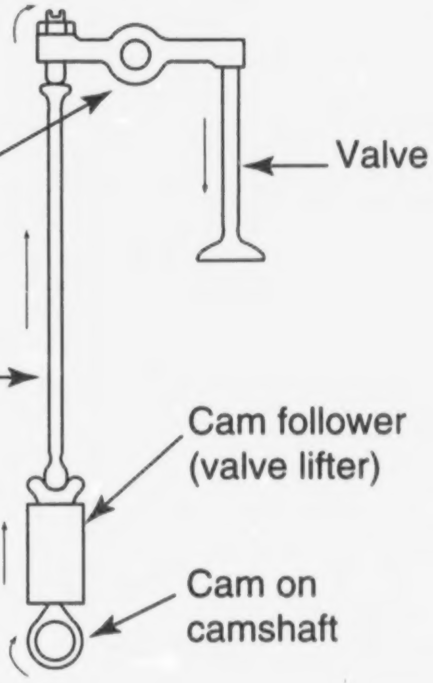
***Permission to duplicate this form is granted.**

Parts of a Cam Lobe

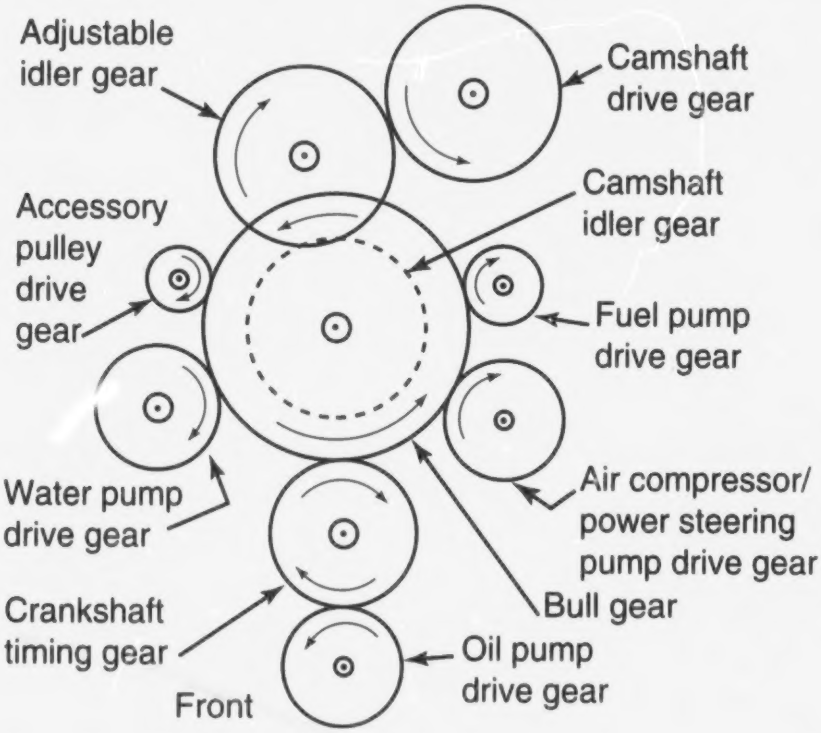

Valve duration in degrees
Valve lift
Base circle


Nose
Opening ramp (flank)
Closing ramp (flank)

Parts of a Valve Train


Rocker arm
Valve
Push rod
Cam follower (valve lifter)
Cam on camshaft

Typical Gear Train Components


Adjustable idler gear
Camshaft drive gear
Camshaft idler gear
Accessory pulley drive gear
Fuel pump drive gear
Air compressor/ power steering pump drive gear
Water pump drive gear
Bull gear
Crankshaft timing gear
Oil pump drive gear
Front

Courtesy of Detroit Diesel Corporation

Unit Contents

Teacher Components

Teacher Page

Suggested Activities 7B-3

Written Test 7B-9

Answers to Written Test 7B-13

Learning Activities Sheet 7B-15

Transparency Masters

1—Cylinder Head Designs 7B-17
2—Parts of a Typical Valve 7B-19
3—Valve Assembly Components 7B-21

Student Components

Student Page

Objective Sheet 7B-3

Information Sheet 7B-5

Assignment Sheet

1—Locate and Label Intake and Exhaust Valves 7B-13

Job Sheets

1—Clean and Inspect a Cylinder Head 7B-15
2—Recondition a Cylinder Head 7B-19
3—Install a Cylinder Head Assembly and Adjust Valves 7B-25

Suggested Activities

Instructional Plan

Preparation

- Read the unit carefully and plan for instruction.
- Review "Teaching Suggestions." Plan for classroom activities.
- Plan your presentation to take advantage of student learning styles and to accommodate special-needs students.
- Prepare classroom. Put up posters and charts and display articles and other references related to this unit.
- Obtain films, videotapes, and other resources to supplement instruction of this unit. See "Resources Used in Developing This Unit" and "Suggested Supplemental Resources" for more information.
- For self-paced instruction, review Learning Activities Sheet. Modify as appropriate to include additional activities and/or resources available in your classroom. Make one copy for each student.
- Make transparencies from the transparency masters included in this unit. These appear in the teacher edition only.

Delivery and Application

Unit Introduction (self-paced instruction)

- Provide student with Learning Activities Sheet and unit of instruction.
- Review unit contents with student.
- Have the student complete the steps in the learning activities sheet.

Unit Introduction (group instruction)

- Provide students with unit of instruction.
- Discuss unit and specific objectives.
- Discuss the information sheet. Implement teaching plan to localize, supplement, and personalize the unit. Reinforce basic academic and workplace skills when applicable.
- Discuss the assignment sheet. Review with students the criteria for evaluation of these activities.

Suggested Activities

- Discuss and demonstrate the job sheets. Make sure all required tools, equipment, and materials are available. Review with students the criteria for evaluation of these activities and the rating scale that will be used to indicate job performance.

Teaching Suggestions

- Show actual examples of the two basic cylinder head designs—cam-in-block and cam-in-head. Point out design differences and discuss the advantages and disadvantages of each.

- Provide students with examples of different types of valves, and have them identify the parts and describe their functions. Also demonstrate valve operation using disassembled or cutaway valves so students can manipulate and understand their different parts and operation.

- Discuss the most common problems that you have encountered with cylinder heads and valves. Describe what may be required to solve each problem.

- Show actual examples of used (but still in good condition) and damaged cylinder heads and valves. Have students examine and distinguish between those that can be reused and those that must be replaced. Provide necessary measuring tools. Also have them identify what might have caused the damage.

- Demonstrate the correct procedures on how to perform required and optional/advanced tasks related to cylinder head assemblies.

  Examples: How to resurface valve seats and faces, how to service injector sleeves, how to set nozzle tip protrusion.

- Review safety rules related to working on cylinder head assemblies and valve reconditioning.

Evaluation

- Make copies of the written test. Add or modify test items as needed. The written test serves as both a pretest and posttest to assist in measuring each student's competency gains.

- Give and evaluate pretest. Modify lesson plan to include additional instruction for those areas where students were deficient.

- Evaluate the assignment sheet. Rate the student using the criteria listed on each assignment sheet. See Answers to Assignment Sheets for correct answers where applicable. If the student's performance is unacceptable, have the student review the appropriate materials and complete the assignment again.

Suggested Activities

- Evaluate the job sheets. When the student is ready to perform a specific task, obtain a copy of the job sheet which may be found in the student edition. Then observe the student performing the procedure.

  Process evaluation—Place a mark in the box to the left of each designated checkpoint if the student has satisfactorily completed the process step(s) for each checkpoint area. If the student is unable to complete the procedure correctly, have the student review the materials and try again.

  Product evaluation—Once the student has satisfactorily completed the procedure, rate the student product (outcome) using the criteria that are provided as part of the job sheet. If the student's product is unacceptable, have the student review the materials and submit another product for evaluation.

  Two sample performance evaluation keys have been provided below. Many other keys are available. Select one rating (grading scale) that best fits your program needs.

  Sample A

  4—**Skilled**—Can perform job with no additional training.
  3—**Moderately skilled**—Has performed job during training program; limited additional training may be required.
  2—**Limited skill**—Has performed job during training program; additional training is required to develop skill.
  1—**Unskilled**—Is familiar with process, but is unable to perform job.
  0—**No exposure**—No information or practice provided during training program.

  Sample B

  Yes—Can perform job with no additional training.
  No—Is unable to perform job satisfactorily.

- Give and evaluate the posttest.

- Meet individually with students to evaluate their progress through this unit of instruction and indicate to them possible areas of improvement.

- Reteach and retest as required.

Resources Used in Developing This Unit

Print Media

- Clark, Elton, et al. *Diesel Fundamentals*. Stillwater, OK: Mid-America Vocational Curriculum Consortium, Inc., 1988.

- Dagel, John F. *Diesel Engine and Fuel System Repair*, 3rd ed. Upper Saddle River, NJ: Prentice Hall, 1994.

- Espenschied, Roland F. *Diesel Engines.* Athens, GA: American Association for Vocational Instructional Materials, 1990.
- *Fundamentals of Service: Engines*, 7th ed. Moline, IL: Deere and Company, 1991.
- *Rebuild Manual, Cummins Diesel 10 Litre Engines.* Columbus, IN: Cummins Engine Co., 1984.
- Schultz, Erich J.*Diesel Mechanics*, 2nd ed. Dallas, TX: Gregg Division/McGraw-Hill, 1993.
- *Series 60 Service Manual.* Detroit, MI: Detroit Diesel Corp., 1995.
- *Service Manual, 3176B Diesel Truck Engine.* Peoria, IL: Caterpillar, Inc., 1995.
- Warren, Larry and John H. Haynes. *Mercedes-Benz Diesel Automotive Repair Manual.*Newbury Park, CA: Haynes Publications, Inc., 1987.

Note: Engine service manuals can be ordered through the local dealership.

Suggested Supplemental Resources

Print Media

- *Failure Analysis–Cylinder Head and Valve Train.* (985586). Available as booklet or slide set. Available from your local Cummins Engine Company dealer/distributor or call:

  Cummins Engine Company Customer Relations
  800-345-5654 or 502-453-8549 or for more information call 1-800-DIESELS

- *Heads, Valves, and Camshafts*

  These training materials may be ordered through your local Caterpillar, Inc. dealership.

Electronic Media

- *Diesel Engine Series*
  - Diesel Cylinder Head Service, VHS, 29 minutes

    Demonstrates the disassembly, inspection, machining, and reassembly of several types of diesel cylinder heads

- Diesel Engine Reassembly, VHS, 23 minutes

  Summarizes how to install the major parts of a diesel engine back onto its short block

- Valves and Cylinder Heads, VHS, 23 minutes

  Covers setting of the flywheel, torquing the head bolts and adjusting valve clearance

The three videos listed above are available from:

Nimco
P.O. Box 9
102 Hwy. 81 N.
Calhoun, KY 42327-0009
1-800-962-6662
www.nimcoinc.com

Written Test

Name ______________________________

Date ______________________ Score __________

Objective 1

Match terms related to a cylinder head assemblies with their definitions. Write your answers in the blanks provided.

1. Cam follower
2. Crosshead (bridge)
3. Fuel injection nozzle
4. Interference angle
5. Poppet valve
6. Turbulence
7. Valve face angle
8. Valve seat angle

_____ a. High velocity swirling of air within the combustion chamber

_____ b. Small difference between valve face angle and valve seat angle that provides a narrow leak-free contact area

_____ c. Intermediate contact between the camshaft and push rod or rocker arm

_____ d. Valve design characterized by a flat sealing disk with a perpendicular stem, opened by a camshaft and closed by a spring.

_____ e. Valve assembly that delivers atomized fuel to the combustion chamber

_____ f. Angle between the valve face and valve stem

_____ g. Allows one rocker arm or cam follower to open two valves at the same time

Objective 2

State one function of the cylinder head.

____

Objective 3

Distinguish between basic cylinder head designs by labeling the following statements with either "CB" for cam-in-block or "CH" for cam-in-head. Definitions continue on the next page.

_____ a. Fewer valve train components; less reciprocating weight

_____ b. Less expensive to manufacture

_____ c. Uses push rods and rocker arms to transfer motion from a block-mounted camshaft

Written Test

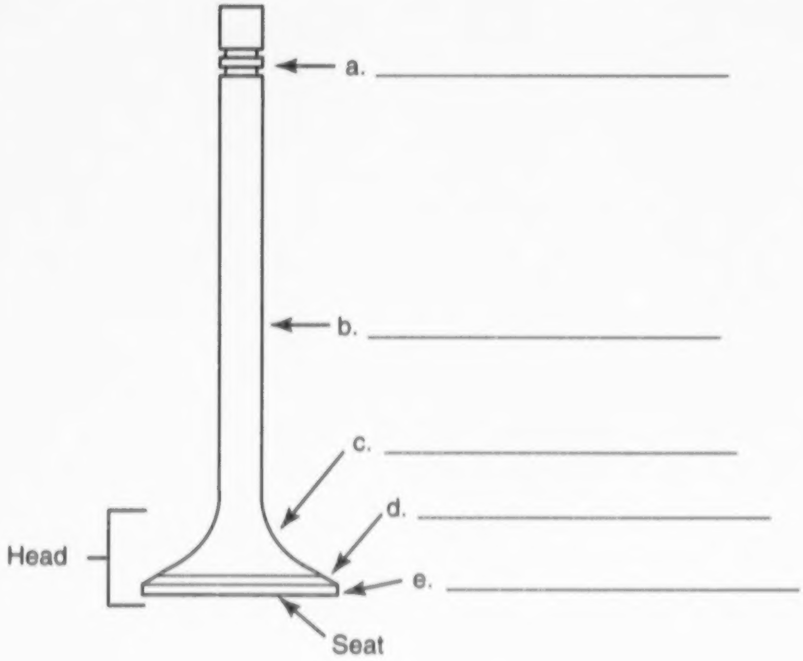
_____ d. Design that mounts the cam over the valves; no push rods

_____ e. Valve train reconditioning requires both block and head service

_____ f. Camshaft is easily accessible for service

Objective 4

Label the parts of a typical valve. Write your answers in the blanks provided.



Objective 5

Match the parts of a valve with their functions. Write your answers in the blanks provided.

1. Face
2. Fillet
3. Head
4. Margin
5. Valve stem
6. Lock grooves

_____ a. Supports the valve in the cylinder head

_____ b. Area between the valve face and head

_____ c. Allow the locks/keepers to anchor the valve spring retainer to the valve stem

_____ d. Provides strength and rigidity for the valve face

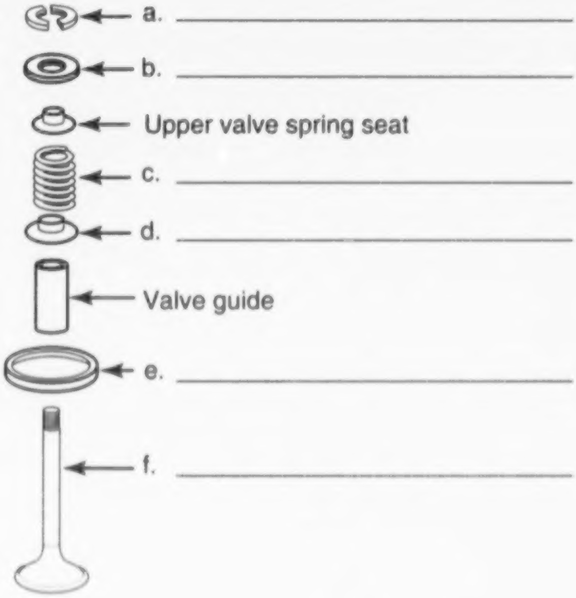
_____ e. Smoothes airflow around the valve face and provides support for the valve head.

_____ f. Machined surface that contacts the valve seat and seals the port.

Written Test

Objective 6

Label basic valve assembly components. Write your answers in the blanks provided.


a. ______________________
b. ______________________
Upper valve spring seat
c. ______________________
d. ______________________
Valve guide
e. ______________________
f. ______________________

Objective 7

Match valve assembly components with their functions. Write your answers in the blanks provided.

1. Valve spring lock
2. Valve rotator
3. Valve seat
4. Valve spring
5. Valve spring retainer
6. Valve stem seal
7. Valve
8. Valve spring seat

_____ a. Locks the valve spring retainer to the valve stem

_____ b. Opens a port in the cylinder head, allowing fresh air to enter the cylinder or spent exhaust gases to leave it

_____ c. Prevents excess oil from entering the valve guide and flowing into the port or cylinder

_____ d. Keeps the valve closed

_____ e. Machined surface in the head that provides a sealing point for the valve face

_____ f. Provides an upper load surface for the valve spring and transmits spring pressure to the valve stem

_____ g. Turns the valve slightly each time it opens

_____ h. Replaceable metal disk that provides a weak surface between the valve spring and cylinder head

Written Test

Objective 8

Arrange in order the steps in the operation of a valve rotator by placing 1-5 in the appropriate blanks.

_____ a. As the valve closes against the valve seat, pressure is removed from the spring washer, and the balls are pushed back to their starting point by the return springs.

_____ b. As the valve opens, valve spring load against the retainer increases, transferring pressure to the spring washer.

_____ c. The compressed spring washer forces the balls to roll down an inclined plane, against the return springs.

_____ d. During valve operation, the tappet/rocker arm applies pressure to the valve stem, compressing the valve spring.

_____ e. This twisting force rotates the entire retainer assembly, which then rotates the valve.

Objective 9

List two common cylinder head problems.

a. ____

b. ____

Objective 10

Select from the following list the common valve/seat problems by placing an "X" in the appropriate blanks.

_____ a. Breakage

_____ b. Valve seat distortion

_____ c. Frozen valve

_____ d. Worn valve guide

_____ e. Burned valve

***Permission to duplicate this test is granted.**

Answers to Written Test

Objective 1

a. 6
b. 4
c. 1
d. 5
e. 3
f. 7
g. 2

Objective 2

Either one of the following:
a. Contains the passages for air, fuel, and coolant
b. Forms the upper part of the combustion chamber

Objective 3

a. CH
b. CB
c. CB
d. CH
e. CB
f. CH

Objective 4

a. Lock grooves
b. Valve stem
c. Fillet
d. Valve face
e. Margin

Objective 5

a. 5
b. 4
c. 6
d. 3
e. 2
f. 1

Objective 6

a. Valve spring lock
b. Valve rotator
c. Valve spring
d. Lower valve spring seat
e. Valve stem seal
f. Valve

Objective 7

a. 1
b. 7
c. 6
d. 4
e. 3
f. 5
g. 2
h. 8

Answers to Written Test

Objective 8	a. 5 b. 2 c. 3 d. 1 e. 4
Objective 9	Any two of the following: a. Warped block/manifold mating surface b. Flame erosion c. Crack in the valve seat d. Crack in the fire deck
Objective 10	a, b, d, e

Prerequisites:
None

Learning Activities Sheet

Student Name ______________________________

Place a checkmark in the appropriate box as you complete each of the steps below.

☐ 1. **Take** Pretest provided by instructor. After test has been evaluated, follow instructor's recommendations.

☐ 2. **Read** Objective Sheet.

☐ 3. **Study** Information Sheet, Objectives 1 through 8.

☐ 4. **Do** Assignment Sheet 1, "Locate and Label Intake and Exhaust Valves."

☐ 5. **Stop** Have instructor evaluate the completed assignment sheet and if the evaluation is satisfactory, continue to step 6. If the evaluation is not satisfactory, repeat steps 3 and 4.

☐ 6. **Study** Information Sheet, Objectives 9 and 10.

Optional

☐ 7. **View** Videotape entitled "Diesel Cylinder Head Service".

☐ 8. **Observe** Demonstration of procedures to be used in completing Job Sheet 1.

☐ 9. **Do** Job Sheet 1, "Clean and Inspect a Cylinder Head."

☐ 10. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to Step 11. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 1 and repeat steps 8 through 10.

☐ 11. **Observe** Demonstration of procedures to be used in completing Job Sheet 2.

☐ 12. **Do** Job Sheet 2, "Recondition a Cylinder Head."

Learning Activities Sheet

☐ 13. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to Step 14. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 2 and repeat steps 11 through 13.

Optional

☐ 14. **View** Videotapes entitled "Diesel Engine Reassembly" and "Valves and Cylinder Heads".

☐ 15. **Observe** Demonstration of procedures to be used in completing Job Sheet 3.

☐ 16. **Do** Job Sheet 3, "Install a Cylinder Head Assembly and Adjust Valves."

☐ 17. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to Step 18. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 3 and repeat steps 15 through 17.

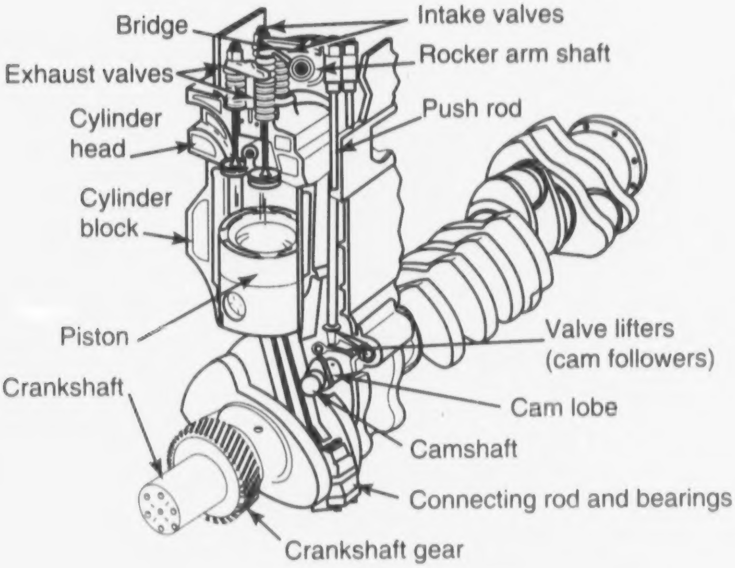
☐ 18. **Check** With instructor for any additional assignments to be completed.

☐ 19. **Take** Posttest provided by instructor. After test has been evaluated, follow instructor's recommendations.

☐ 20. **Stop** Have instructor evaluate your unit performance. If the evaluation is satisfactory, proceed to next learning activities sheet. If evaluation is not satisfactory, ask instructor for further instructions.

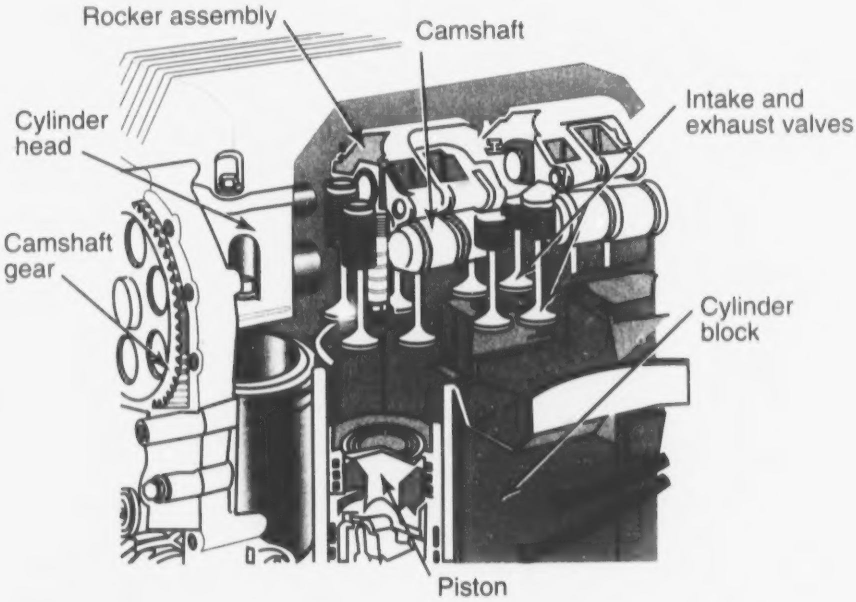
***Permission to duplicate this form is granted.**

Cylinder Head Designs


Bridge
Exhaust valves
Cylinder head
Cylinder block
Piston
Crankshaft
Intake valves
Rocker arm shaft
Push rod
Valve lifters (cam followers)
Cam lobe
Camshaft
Connecting rod and bearings
Crankshaft gear

Cam-in-block

Courtesy of Cummins Engine Company, Inc.

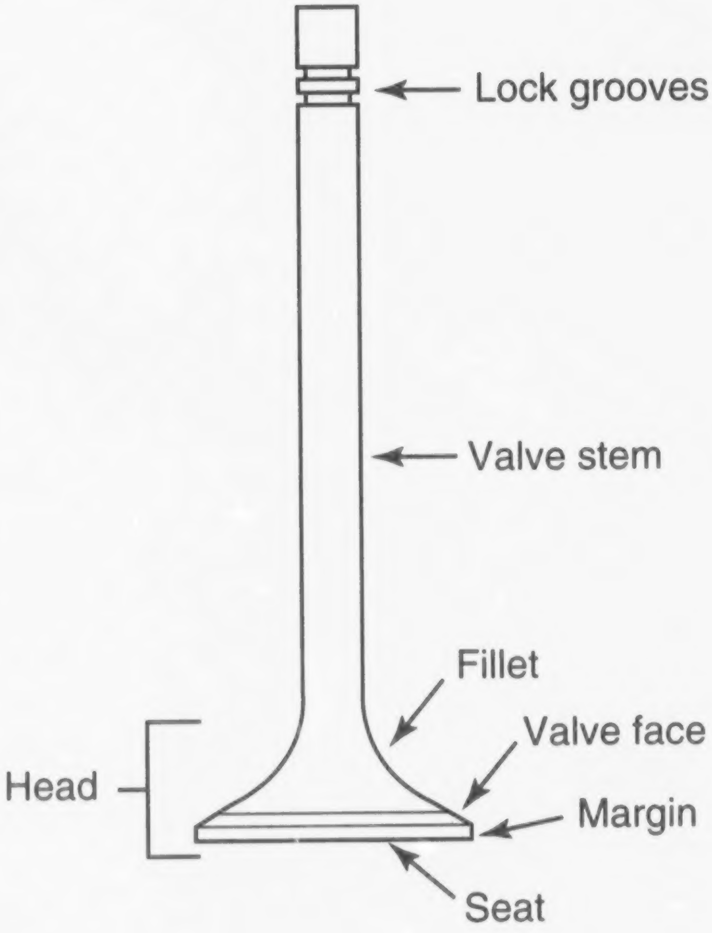

Rocker assembly
Camshaft
Cylinder head
Intake and exhaust valves
Camshaft gear
Cylinder block
Piston

Cam-in-head

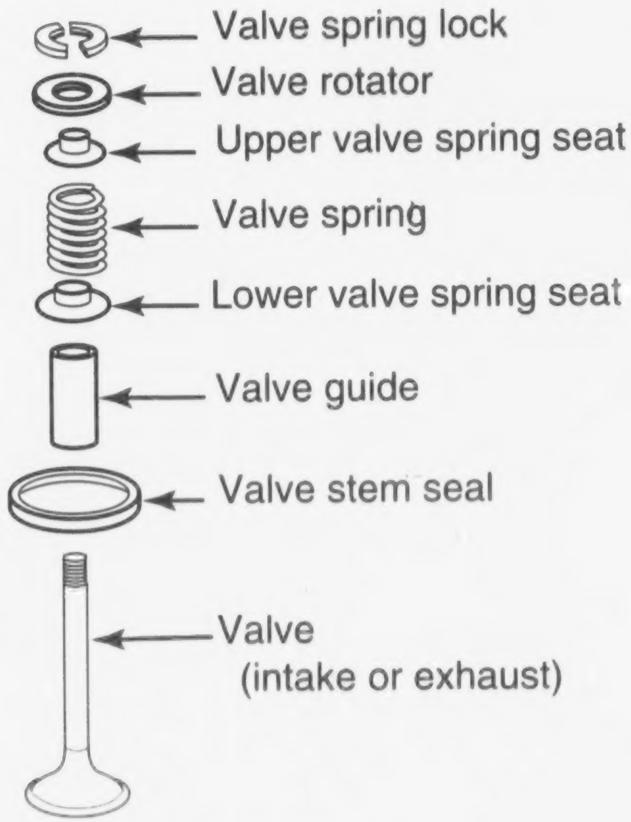
Courtesy of Detroit Diesel Corporation

TM 1

Parts of a Typical Valve


Lock grooves
Valve stem
Fillet
Valve face
Head
Margin
Seat

Valve Assembly Components


Valve spring lock
Valve rotator
Upper valve spring seat
Valve spring
Lower valve spring seat
Valve guide
Valve stem seal
Valve
(intake or exhaust)

Unit 8-B Air Induction and Exhaust Systems

Unit Contents

Teacher Components

Teacher Page

Suggested Activities 8B-3

Written Test 8B-9

Answers to Written Test 8B-17

Learning Activities Sheet 8B-19

Transparency Masters

1—Basic Air Induction Components 8B-23
2—Main Parts of a Turbocharger 8B-25
3—Basic Exhaust Components 8B-27
4—Parts of a Typical Catalytic Converter 8B-29

Student Components

Student Page

Objective Sheet 8B-3

Information Sheet 8B-5

Job Sheets

1—Inspect and Test Air Induction System 8B-13
2—Inspect and Service Turbo/Supercharger
and Related Components 8B-17
3—Clean and Test Jacket Water Intercooler 8B-21
4—Clean and Test Air-to-Air Intercooler 8B-25
5—Inspect and Test Exhaust System 8B-29
6—Inspect Starting Preheater Controls 8B-33
7—Test Starting Fluid System and Controls 8B-37

Suggested Activities

Instructional Plan

Preparation

- Read the unit carefully and plan for instruction.
- Review "Teaching Suggestions." Plan for classroom activities.
- Plan your presentation to take advantage of student learning styles and to accommodate special-needs students.
- Prepare classroom. Put up posters and charts and display articles and other references related to this unit.
- Obtain films, videotapes, and other resources to supplement instruction of this unit. See "Resources Used in Developing This Unit" and "Suggested Supplemental Resources" for more information.
- For self-paced instruction, review Learning Activities Sheet. Modify as appropriate to include additional activities and/or resources available in your classroom. Make one copy for each student.
- Make transparencies from the transparency masters included in this unit. These appear in the teacher edition only.

Delivery and Application

Unit Introduction (self-paced instruction)

- Provide student with Learning Activities Sheet and unit of instruction.
- Review unit contents with student.
- Have the student complete the steps in the learning activities sheet.

Unit Introduction (group instruction)

- Provide students with unit of instruction.
- Discuss unit and specific objectives.
- Discuss the information sheet. Implement teaching plan to localize, supplement, and personalize the unit. Reinforce basic academic and workplace skills when applicable.

Suggested Activities

- Discuss and demonstrate the job sheets. Make sure all required tools, equipment, and materials are available. Review with students the criteria for evaluation of these activities and the rating scale that will be used to indicate job performance.

Teaching Suggestions

- Discuss the different types of air induction and exhaust systems, and point out the advantages and disadvantages of each type and the most common applications of the various types.
- Have students identify the parts of a turbocharger (or supercharger) using an actual component available in the shop. Discuss the functions of each part. Disassemble and have students practice reassembling.
- Make a display of the various starting aid devices. Discuss when and how they are used.
- Use an actual vehicle available in the shop or a mock-up to show the basic operation of an induction and exhaust system.
- Cut apart a catalytic converter to show the layers and components. Discuss with student the operating principles of a catalytic converter.
- Discuss the most common problems that you have encountered with air induction and exhaust systems. Describe what may be required to solve each problem.

Evaluation

- Make copies of the written test. Add or modify test items as needed. The written test serves as both a pretest and posttest to assist in measuring each student's competency gains.
- Give and evaluate pretest. Modify lesson plan to include additional instruction for those areas where students were deficient.
- Evaluate the job sheets. When the student is ready to perform a specific task, obtain a copy of the job sheet which may be found in the student edition. Then observe the student performing the procedure.

  Process evaluation—Place a mark in the box to the left of each designated checkpoint if the student has satisfactorily completed the process step(s) for each checkpoint area. If the student is unable to complete the procedure correctly, have the student review the materials and try again.

Product evaluation—Once the student has satisfactorily completed the procedure, rate the student product (outcome) using the criteria that are provided as part of the job sheet. If the student's product is unacceptable, have the student review the materials and submit another product for evaluation.

Two sample performance evaluation keys have been provided below. Many other keys are available. Select one rating (grading scale) that best fits your program needs.

Sample

4—**Skilled**—Can perform job with no additional training.
3—**Moderately skilled**—Has performed job during training program; limited additional training may be required.
2—**Limited skill**—Has performed job during training program; additional training is required to develop skill.
1—**Unskilled**—Is familiar with process, but is unable to perform job.
0—**No exposure**—No information or practice provided during training program.

Sample B

Yes—Can perform job with no additional training.
No—Is unable to perform job satisfactorily.

- Give and evaluate the posttest.
- Meet individually with students to evaluate their progress through this unit of instruction and indicate to them possible areas of improvement.
- Reteach and retest as required.

Resources Used in Developing This Unit

Print Media

- Clark, Elton, et al. *Diesel Fundamentals*. Stillwater, OK: Mid-America Vocational Curriculum Consortium, Inc., 1988.
- Dagel, John F. *Diesel Engine and Fuel System Repair*, 3rd ed. Upper Saddle River, NJ: Prentice Hall, 1994.
- Espenschied, Roland F. *Diesel Engines*. Athens, GA: American Association for Vocational Instructional Materials, 1990.
- *Fundamentals of Service: Engines*, 7th ed. Moline, IL: Deere and Company, 1991.
- *Rebuild Manual, Cummins Diesel 10 Litre Engines*. Columbus, IN: Cummins Engine Co.
- *Series 60 Service Manual*. Detroit, MI: Detroit Diesel Corp., 1995.

Suggested Activities

- *Service Manual, 3176B Diesel Truck Engine.* Peoria, IL: Caterpillar, Inc., 1995.
- *Service Manual, 3600 Series Engines.* Peoria, IL: Caterpillar, Inc., 1995.

  Note: Engine service manuals can be ordered through the local dealership.

Suggested Supplemental Resources

Print Media

- *Troubleshooting–Air Induction System.* Available as booklet, slide set, or audio tape.
- *Troubleshooting–Air Exhaust System.* Available as booklet, slide set, or audio tape.
- *Turbocharger Failure Analysis.* Available as booklet, slide set, or audio tape.

  The above are available from your local Cummins Engine Company dealer/distributor or call:

  Cummins Engine Company Customer Relations
  800-345-5654 or 502-453-8549 or for more information call 1-800-DIESELS

- *ASE Test Prep Series*—Medium/Heavy Duty Truck, 2nd ed. (Diesel Engines). Albany, NY: Delmar Publishers, 2002.

  Also available on CD ROM format

- Bennett, Sean. *Medium/Heavy Duty Truck Engines, Fuel and Computerized Management Systems.* Albany, NY: Delmar Publishers, 1999.
- Bennett, Sean. *Today's Technician: Medium/Heavy Duty Truck Diesel Engines.* Albany, NY: Delmar Publishers, 2001.
- Brady, Robert. *Diesel Engine and Fuel System Repair*, 5th ed. Upper Saddle River, NJ: Prentice Hall Inc., 2002.
- *Turbocharger Failure Analysis Service Manual.* (21-1.1) Available from:

  Mack Trucks, Inc.
  2100 Mack Boulevard
  P.O. Box M
  Allentown, PA 18105-5000
  610-439-3011

- *Turbocharger Failure Analysis* (SEBV0550(), 18-page book. (1988). Available from your local CAT dealer or write the following for more information:

  Caterpillar Service Training
  600 W. Washington St., Bldg. JJ
  East Peoria, IL 61630

Electronic Media

- *Turbochargers*, VHS, 22 minutes

  Summarizes how to troubleshoot, test, remove, service, and install turbochargers.

- *Superchargers*, VHS, 25 minutes

  Summarizes how to troubleshoot, test, remove, service, and install superchargers.

  The videos listed above are available from:

  Nimco
  P.O. Box 9
  102 Hwy. 81 North
  Calhoun, KY 42327-0009
  1-800-962-6662
  www.nimcoinc.com

Written Test

Name ____

Date ______________________________ Score__________

Objective 1

Match terms related to basic air induction and exhaust systems with their definitions. Write the corresponding numbers on the blanks provided.

1. Air restriction indicator
2. Blower
3. Monolith
4. Naturally aspirated
5. Scavenging
6. Supercharging
7. Turbocharging

_____ a. Forcing air into the cylinders above atmospheric pressure; involves direct mechanical connection to engine

_____ b. Using fresh intake air to evacuate burnt exhaust gases from the cylinder

_____ c. Indicates increasing restriction in the induction system due to a dirty filter element or a damaged component

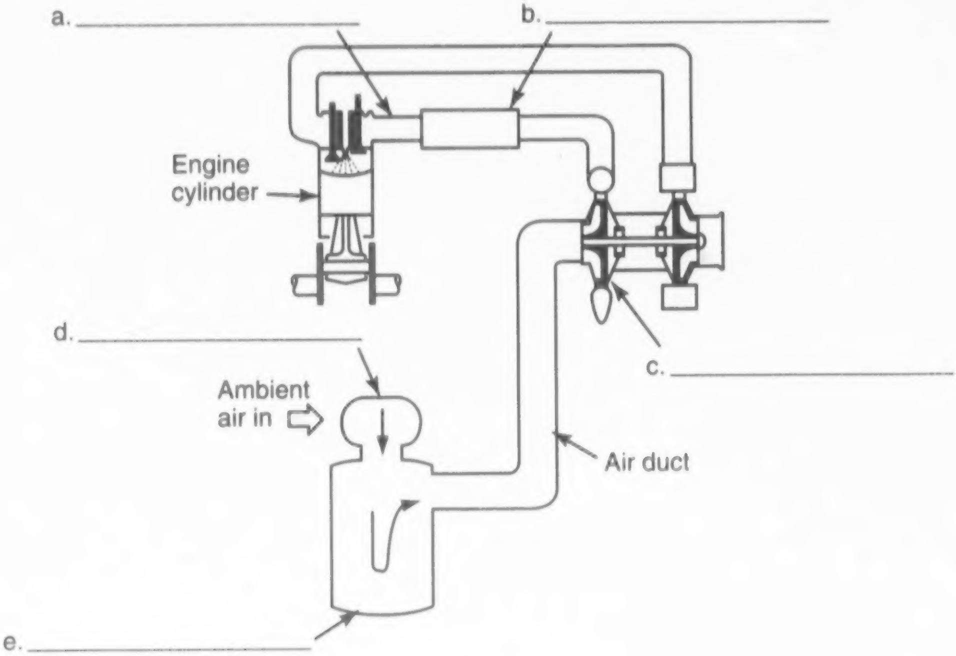
_____ d. Using an exhaust-driven compressor unit to force air into the cylinders; no direct mechanical connection to engine

_____ e. Engine that does not use superchargers or turbochargers

Written Test

Objective 2

Label the basic air induction system components on the illustration below.



Objective 3

Match the air induction components with their correct functions. Write the corresponding numbers on the blanks provided.

1. Air filter
2. Compressor
3. Intake manifold
4. Intercooler/ aftercooler
5. Prefilter/precleaner

_____ a. Channels the air to the individual intake ports

_____ b. Removes large dust particles from the intake air before it enters the air cleaner

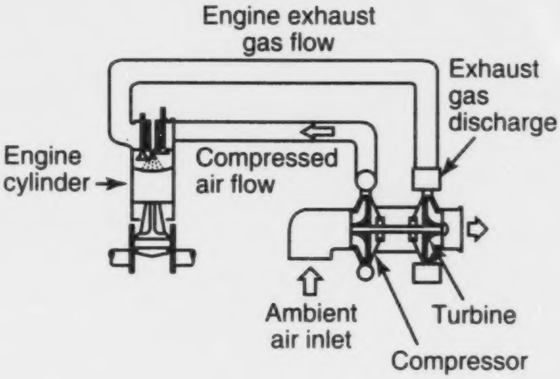
_____ c. Cools the compressed air before sending it into the intake manifold

_____ d. Pressurizes the air entering the engine; provides greater cylinder filling

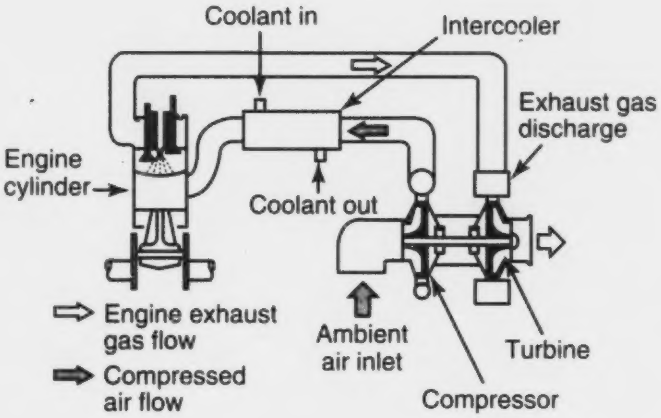
_____ e. Removes grit and fine dust particles; provides engine with the required volume of clean air

Objective 4

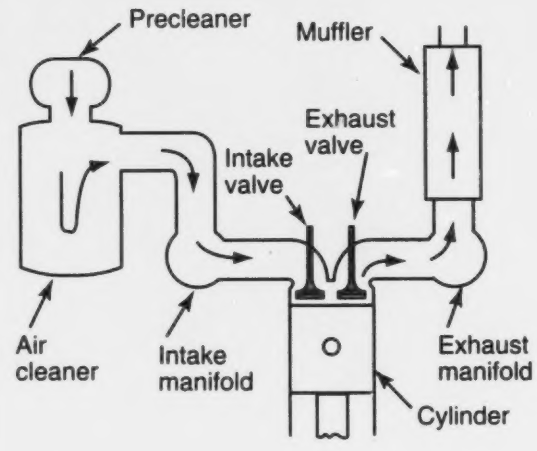
Identify the following types of air induction systems. Write your answers in the blanks provided.


Engine exhaust gas flow
Exhaust gas discharge
Engine cylinder
Compressed air flow
Ambient air inlet
Turbine
Compressor

a. ______________________________


Coolant in
Intercooler
Exhaust gas discharge
Engine cylinder
Coolant out
Engine exhaust gas flow
Compressed air flow
Ambient air inlet
Turbine
Compressor

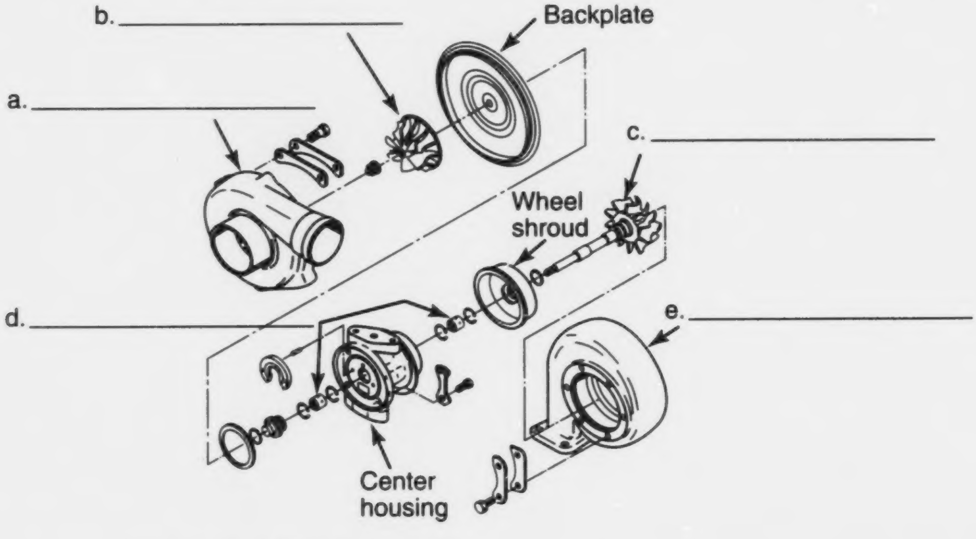
b. ______________________________


Precleaner
Muffler
Exhaust valve
Intake valve
Air cleaner
Intake manifold
Exhaust manifold
Cylinder

c. ______________________________

Objective 5

Label the main parts of a turbocharger on the illustration below.


b. ____________
Backplate
a. ____________
c. ____________
Wheel shroud
d. ____________
e. ____________
Center housing

Courtesy of Detroit Diesel Corporation

Objective 6

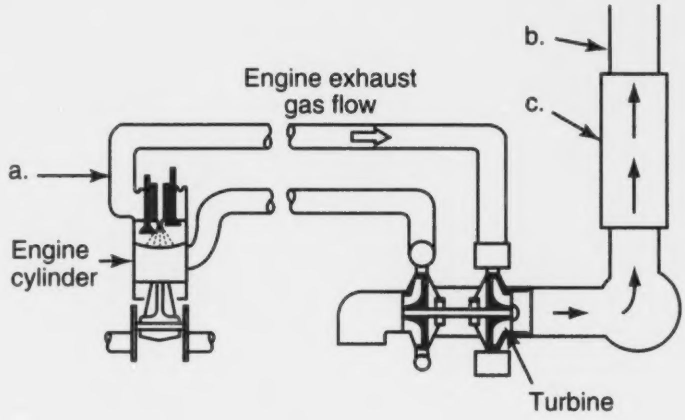
List two starting aid devices.

a. ______________________________

b. ______________________________

Objective 7

Identify the exhaust system components shown below. Write your answers in the blanks provided.



a. ______________________________

b. ______________________________

c. ______________________________

Objective 8

Match exhaust system components on the right with their correct functions. Write the corresponding numbers on the blanks provided.

1. Exhaust manifold
2. Exhaust pipe
3. Muffler
4. Turbine

_____ a. Channels exhaust gases from the discharge side of the turbocharger turbine to the muffler (if equipped) or to the atmosphere

_____ b. Uses exhaust gas heat and pressure to rotate and drive the compressor on the other side of the turbocharger

_____ c. Routes hot gases from the exhaust ports to the inlet side of the turbocharger turbine

_____ d. Absorbs and redirects the sound waves from the exhaust gases; greatly reduces exhaust noise

Written Test

Objective 9

Arrange in order the following steps for an air induction and exhaust system by placing the correct sequence numbers (1-7) in the appropriate blanks.

_____ a. The compressed (and heated) air is sent to the intercooler, where it is cooled and condensed.

_____ b. The exhaust flow exits the turbine housing and flows through the muffler where it is quieted.

_____ c. Exhaust is then sent to the tailpipe or exhaust stack. The spinning turbine is connected by a shaft to the compressor, which is also turning.

_____ d. The dense compressed air flows from the intercooler, through the intake manifold, to each cylinder intake port.

_____ e. Hot, expanding exhaust gases leave the exhaust port and are channeled through the exhaust manifold to the turbine side of the turbocharger. These gases strike the turbine blades, causing them to spin.

_____ f. The compressor pulls in filtered air and compresses it.

_____ g. Inside the cylinder, the air is mixed with fuel, burned, and then pushed out the exhaust port.

Objective 10

Complete the following statements concerning the scavenging process for two-stroke and four-stroke diesel engines by circling the correct answers.

a. Two-stroke engines

- As the piston nears the end of the **(intake, power)** stroke, the exhaust valves open, allowing exhaust gases to begin leaving the cylinder.
- As the piston continues to move downward, the **(inlet, exit)** ports are uncovered.
- Compressed air from the **(blower, turbocharger)** enters the cylinder through the inlet ports, driving out the remaining exhaust gas.

b. Four-stroke engines

- At the end of the power stroke, just before the piston reaches **(BDC, TDC)**, the exhaust valves begin to open.
- The piston **(rises, falls)**, pushing the exhaust gases out of the cylinder.
- Just before the piston reaches TDC, the **(intake, exhaust)** valves begin to open. This allows fresh compressed air to enter the cylinder, driving out the remaining exhaust gas.

Objective 11

Distinguish between agricultural/industrial and motor vehicle exhaust systems by placing an "A" next to agricultural or industrial diesel engine statements, or an "M" next to motor vehicle statements.

_____ a. Exhaust pipes are typically used to carry smoke and noise away from the immediate area of the engine.

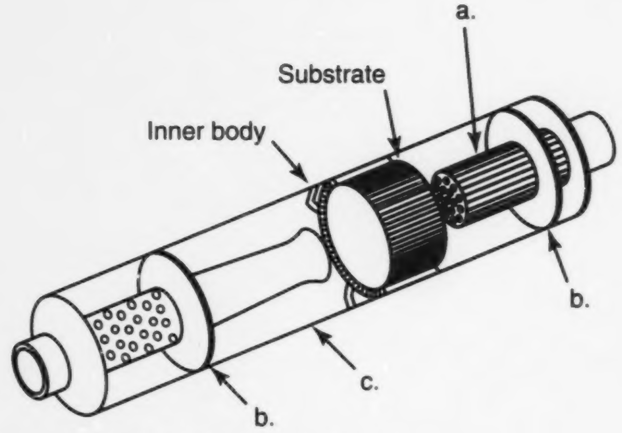
_____ b. Tailpipes must route exhaust gases away from the underside of the vehicle to prevent trapping carbon monoxide.

_____ c. Effective mufflers are required to reduce sound levels to acceptable limits.

_____ d. Sound dampening is not as critical; some turbocharged engines do not use mufflers at all.

Objective 12

Identify the parts of a typical catalytic converter shown below. Write your answers in the blanks provided.



Courtesy of Cummins Engine Company, Inc.

a. ______________________ b. ______________________

c. ______________________

Objective 13

Complete statements concerning the operation of a catalytic converter by filling in the blanks with the correct answers.

a. Exhaust gas enters the converter and passes through the reducing catalyst. This reduces the ______________________ level.

b. The exhaust gas next passes through the oxidizing part of the converter. This area converts the HC (hydrocarbons) and CO (carbon monoxide) into _____ and _____.

c. As this reduction reaction takes place, the converter generates tremendous amounts of ______________________.

*Permission to duplicate this test is granted.

Answers to Written Test

Objective 1

a. 6
b. 5
c. 1
d. 7
e. 4

Objective 2

a. Intake manifold
b. Intercooler (or aftercooler)
c. Compressor
d. Prefilter (or precleaner)
e. Air Filter

Objective 3

a. 3
b. 5
c. 4
d. 2
e. 1

Objective 4

a. Turbocharged
b. Turbocharged and intercooled
c. Naturally aspirated

Objective 5

a. Compressor housing
b. Compressor wheel
c. Turbine wheel assembly
d. Bearings
e. Turbine housing

Objective 6

Any two of the following:
a. Block heaters/preheaters
b. Glow plugs
c. Starting fluid injection

Objective 7

a. Exhaust manifold
b. Exhaust pipe
c. Muffler

Objective 8

a. 2
b. 4
c. 1
d. 3

Answers to Written Test

Objective 9

a. 5
b. 2
c. 3
d. 6
e. 1
f. 4
g. 7

Objective 10

a. Two-stroke
  - Power
  - Inlet
  - Blower

b. Four-stroke
  - BDC
  - Rises
  - Intake

Objective 11

a. A
b. M
c. M
d. A

Objective 12

a. Muffler
b. Baffle(s)
c. Canister

Objective 13

a. NO_X (oxides of nitrogen)
b. H_2O and CO_2
c. Heat

Prerequisites:
None

Learning Activities Sheet

Student Name ______________________________

Place a checkmark in the appropriate box as you complete each of the steps below.

☐ 1. **Take** Pretest provided by instructor. After test has been evaluated, follow instructor's recommendations.

☐ 2. **Read** Objective Sheet.

☐ 3. **Study** Information Sheet, Objectives 1 through 4.

☐ 4. **Observe** Demonstration of procedures to be used in completing Job Sheet 1.

☐ 5. **Do** Job Sheet 1, "Inspect and Test Air Induction System."

☐ 6. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to Step 7. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 1 and repeat steps 4 through 6.

☐ 7. **Study** Information Sheet, Objective 5.

Optional

☐ 8. **View** Videotape(s) entitled "Turbochargers" and/or "Superchargers".

☐ 9. **Observe** Demonstration of procedures to be used in completing Job Sheet 2.

☐ 10. **Do** Job Sheet 2, "Inspect and Service Turbo/Supercharger and Related Components."

☐ 11. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to Step 12. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 2 and repeat steps 9 through 11.

☐ 12. **Study** Information Sheet, Objectives 6 through 13.

☐ 13. **Observe** Demonstration of procedures to be used in completing Job Sheet 3.

☐ 14. **Do** Job Sheet 3, "Clean and Test Jacket Water Intercooler."

☐ 15. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to Step 16. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 3 and repeat steps 13 through 15.

☐ 16. **Observe** Demonstration of procedures to be used in completing Job Sheet 4.

☐ 17. **Do** Job Sheet 4, "Clean and Test Air-to-Air Intercooler."

☐ 18. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to Step 19. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 4 and repeat steps 16 through 18.

☐ 19. **Observe** Demonstration of procedures to be used in completing Job Sheet 5.

☐ 20. **Do** Job Sheet 5, "Inspect and Test Exhaust System."

☐ 21. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to Step 22. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 5 and repeat steps 19 through 21.

☐ 22. **Observe** Demonstration of procedures to be used in completing Job Sheet 6.

☐ 23. **Do** Job Sheet 6, "Inspect Starting Preheating Controls."

☐ 24. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to Step 25. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 6 and repeat steps 22 through 24.

☐ 25. **Observe** Demonstration of procedures to be used in completing Job Sheet 7.

☐ 26. **Do** Job Sheet 7, "Test Starting Fluid System and Controls."

☐ 27. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to Step 28. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 7 and repeat steps 25 through 27.

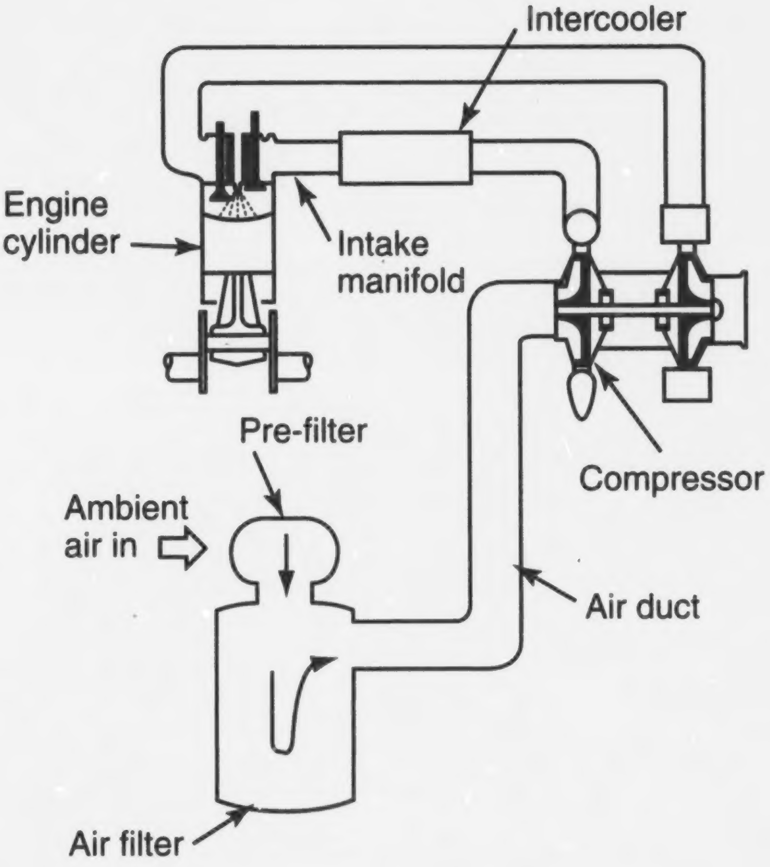
☐ 28. **Check** With instructor for any additional assignments to be completed.

☐ 29. **Take** Posttest provided by instructor. After test has been evaluated, follow instructor's recommendations.

☐ 30. **Stop** Have instructor evaluate your unit performance. If the evaluation is satisfactory, proceed to next learning activities sheet. If evaluation is not satisfactory, ask instructor for further instructions.

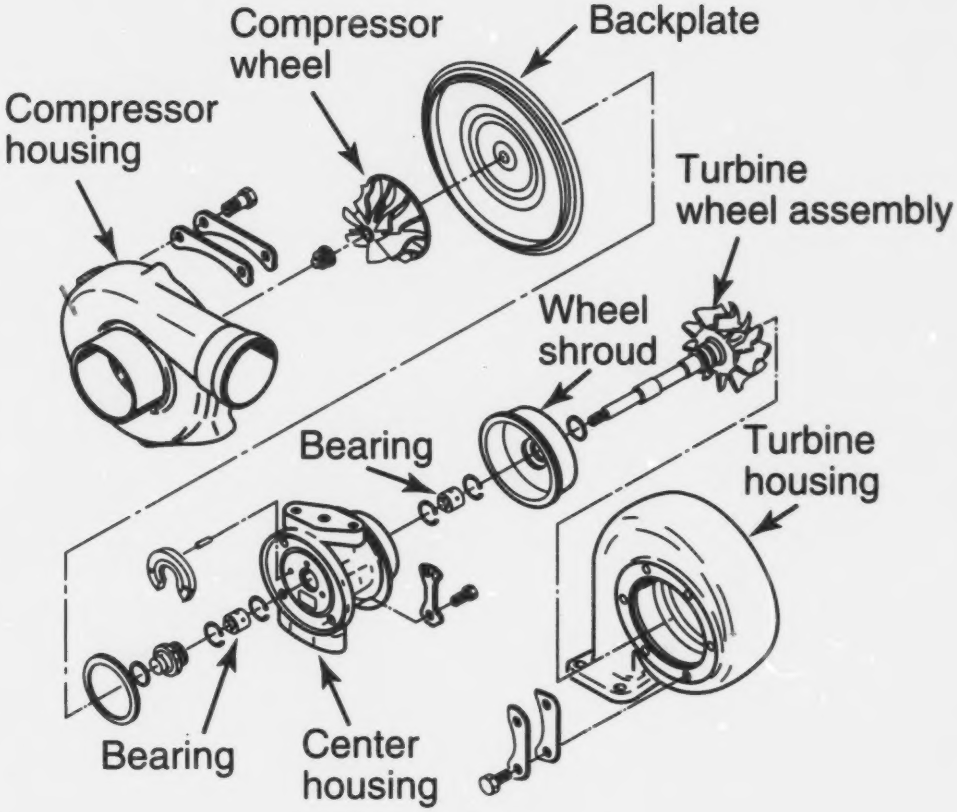
***Permission to duplicate this form is granted.**

Basic Air Induction Components


Intercooler
Engine cylinder
Intake manifold
Compressor
Pre-filter
Ambient air in
Air duct
Air filter

TM 1

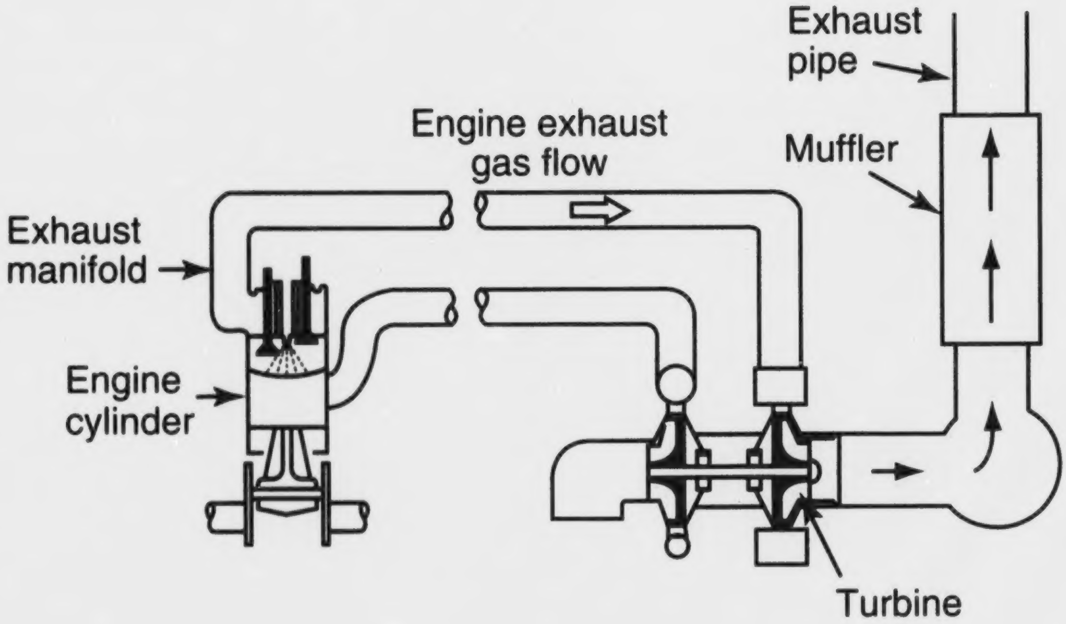
Main Parts of a Turbocharger


Compressor wheel
Backplate
Compressor housing
Turbine wheel assembly
Wheel shroud
Bearing
Turbine housing
Bearing
Center housing

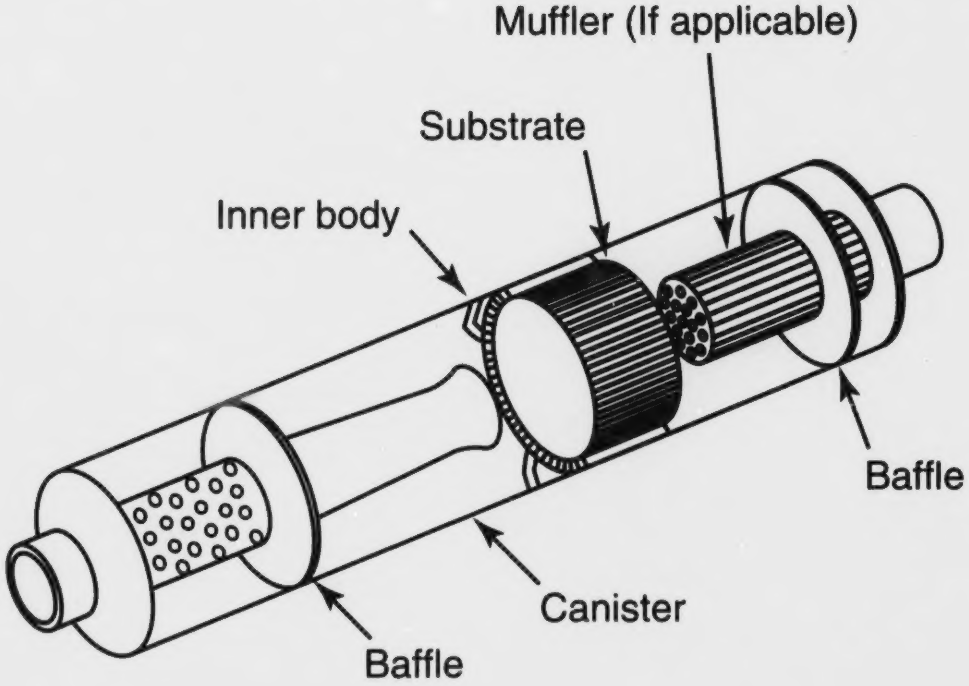
Courtesy of Detroit Diesel Corporation

TM 2

Basic Exhaust Components


Exhaust pipe
Engine exhaust gas flow
Muffler
Exhaust manifold
Engine cylinder
Turbine

Parts of a Typical Catalytic Converter


Muffler (If applicable)
Substrate
Inner body
Baffle
Canister
Baffle

Courtesy of Cummins Engine Company, Inc.

Unit 9-B Engine Brakes and Retarders

Unit Contents

Teacher Page

Teacher Components

Suggested Activities 9B–3

Written Test 9B–7

Answers to Written Test 9B–15

Learning Activities Sheet 9B–17

Transparency Masters

1—Engine Compression Brake Components 9B–21
2—Exhaust Brake Components 9B–23
3—Hydraulic Engine Retarder Components (BrakeSaver®) 9B–25
4—Electric Driveline Retarder Components 9B–27

Student Page

Student Components

Objective Sheet 9B–3

Information Sheet 9B–5

Job Sheets

1—Remove, Inspect, Install and Adjust
a Jacobs Engine Brake 9B–13
2—Check Operation of a BrakeSaver® 9B–17
3—Check Operation of an Exhaust Brake 9B–21
4—Remove, Clean, and Reinstall an Exhaust Brake 9B–25
5—Check Operation of a Driveline Retarder 9B–29

Suggested Activities

Instructional Plan

Preparation

- Read the unit carefully and plan for instruction.
- Review "Teaching Suggestions." Plan for classroom activities.
- Plan your presentation to take advantage of student learning styles and to accommodate special-needs students.
- Prepare classroom. Put up posters and charts and display articles and other references related to this unit.
- Obtain films, videotapes, and other resources to supplement instruction of this unit. See "Resources Used in Developing This Unit" and "Suggested Supplemental Resources" for more information.
- For self-paced instruction, review Learning Activities Sheet. Modify as appropriate to include additional activities and/or resources available in your classroom. Make one copy for each student.
- Make transparencies from the transparency masters included in this unit. These appear in the teacher edition only.

Delivery and Application

Unit Introduction (self-paced instruction)

- Provide student with Learning Activities Sheet and unit of instruction.
- Review unit contents with student.
- Have the student complete the steps in the learning activities sheet.

Unit Introduction (group instruction)

- Provide students with unit of instruction.
- Discuss unit and specific objectives.
- Discuss the information sheet. Implement teaching plan to localize, supplement, and personalize the unit. Reinforce basic academic and workplace skills when applicable.
- Discuss and demonstrate the job sheets. Make sure all required tools, equipment, and materials are available. Review with students the criteria for evaluation of these activities and the rating scale that will be used to indicate job performance.

Teaching Suggestions

- Discuss the different types of engine brakes and retarders used on diesel engine vehicles. Point out the advantages and disadvantages of each type and the most common applications of the basic types.

Suggested Activities

- Have students identify the components of typical engine brakes and retarders using actual components available in the shop. Discuss the functions of each part. Disassemble and have students practice reassembling.
- Use an actual vehicle available in the shop or a mock-up to show the basic operation of engine brakes and retarders.
- Discuss the most common problems that you have encountered with engine brakes and retarders. Describe what may be required to solve each problem.
- Use OEM manuals from engine brake and retarder manufacturers to demonstrate the procedures required in the job sheets.

Evaluation

- Make copies of the written test. Add or modify test items as needed. The written test serves as both a pretest and posttest to assist in measuring each student's competency gains.
- Give and evaluate pretest. Modify lesson plan to include additional instruction for those areas where students were deficient.
- Evaluate the job sheets. When the student is ready to perform a specific task, obtain a copy of the job sheet which may be found in the student edition. Then observe the student performing the procedure.

  Process evaluation—Place a mark in the box to the left of each designated checkpoint if the student has satisfactorily completed the process step(s) for each checkpoint area. If the student is unable to complete the procedure correctly, have the student review the materials and try again.

  Product evaluation—Once the student has satisfactorily completed the procedure, rate the student product (outcome) using the criteria that are provided as part of the job sheet. If the student's product is unacceptable, have the student review the materials and submit another product for evaluation.

  Two sample performance evaluation keys have been provided below. Many other keys are available. Select one rating (grading scale) that best fits your program needs.

  Sample A

  4—**Skilled**—Can perform job with no additional training.
  3—**Moderately skilled**—Has performed job during training program; limited additional training may be required.
  2—**Limited skill**—Has performed job during training program; additional training is required to develop skill.
  1—**Unskilled**—Is familiar with process, but is unable to perform job.
  0—**No exposure**—No information or practice provided during training program.

Sample B

Yes—Can perform job with no additional training.
No—Is unable to perform job satisfactorily.

- Give and evaluate the posttest.
- Meet individually with students to evaluate their progress through this unit of instruction and indicate to them possible areas of improvement.
- Reteach and retest as required.

Resources Used in Developing This Unit

Print Media

- Clark, Elton, et al. *Diesel Fundamentals.* Stillwater, OK: Mid-America Vocational Curriculum Consortium, Inc., 1988.
- Dagel, John F. *Diesel Engine and Fuel System Repair*, 3rd ed. Upper Saddle River, NJ: Prentice Hall, 1994.
- Espenschied, Roland F. *Diesel Engines.* Athens, GA: American Association for Vocational Instructional Materials, 1990.
- *Fundamentals of Service: Engines* 7th ed. Moline, IL: Deere and Company, 1991.
- *Rebuild Manual, Cummins Diesel 10 Litre Engines.* Columbus, IN: Cummins Engine Co. 1984.
- *Series 60 Service Manual.* Detroit, MI: Detroit Diesel Corp., 1995.
- *Service Manual, 3176B Diesel Truck Engine.* Peoria, IL: Caterpillar, Inc., 1995.
- *Service Manual, 3600 Series Engines.* Peoria, IL: Caterpillar, Inc., 1995.

Note: Engine service manuals can be ordered through the local dealership.

Suggested Supplemental Resources

Print Media

- *Jake Brake Model 340A Installation Manual.* Designed for Caterpillar 3406E engines.
- *Jake Brake Models 450A/450B Parts Manual.* Designed for Cummins N14 engines.
- *Jake Brake Models 680A/B Installation Manual.* Designed for Mack E6 engines.
- *Jake Brake Models 760/760A/765 Installation Manual.* Designed for Detroit Diesel Series 60 engines.

The above are available from:

Jacobs Vehicle Equipment Company
22 East Dudley Town Road
Bloomfield, CT 06002

Phone: 203-243-1441 or Fax: 203-243-7609
www.jakebrake.com

- Information booklets and illustrations on Jake Brake theory, features, and benefits

  — Engine brake

  — Exhaust brake

  — Driveline brake

  For information concerning the availability and suitability of these materials, contact:

  Technical Training Department
  Jacobs Vehicle Systems
  (800) 876-5253
  www.jakebrake.com

- Telma Driveline Retarders

  For more information, contact:

  Telma Retarder, Inc.
  1521 Morse Avenue
  Elk Grove Village, IL 60007
  (847) 593-1098
  www.telma.com

- *ASE Test Prep Series* — Medium/Heavy Duty Truck, 2nd ed. (Diesel Engines). Albany, NY: Delmar Publishers, 2002.

  Also available in CD ROM format.

- Bennett, Sean. *Today's Technician: Medium/Heavy Duty Truck Diesel Engines.* Albany, NY: Delmar Publishers, 2001.

- Brady, Robert. *Diesel Engine and Fuel System Repair*, 5th ed. Upper Saddle River, NJ: Prentice Hall Inc., 2002.

Electronic Media

- Blue Ox Exhaust Brake Design, Operation, and Service, VHS, 20 minutes. For information concerning availability of this material, contact:

  Technical Support Department
  Williams Controls, Inc.
  14100 SW 72nd Avenue
  Portland, OR 97224
  (503) 684-8600
  www.wmco.com

Written Test

Name ____

Date ______________________________ Score__________

Objective 1

Match terms related to engine brakes and retarders with their definitions. Write your answers in the blanks provided.

1. Air suppressor
2. Clutch switch
3. Eddy current
4. Electronic control module
5. Engine brake
6. Master piston
7. Pump switch
8. Retarder
9. Rheostat
10. Slave piston

_____ a. Switch that disengages compression brake when clutch is depressed

_____ b. Manually operated switch that varies current flow

_____ c. Device that causes the vehicle to slow down by releasing the compressed air normally needed for ignition

_____ d. Device that stops air pulsations

_____ e. Computerized device that monitors other electronic parts by receiving and sending electronic signals

_____ f. Any device that slows the vehicle

_____ g. Piston that is directly responsive to master piston; operates exhaust valves

_____ h. Circular current produced along coil windings; generates both heat and resistance to movement

Written Test

Objective 2

Match common types of engine brakes and retarders with their descriptions. Write your answers in the blanks provided.

1. Driveline retarder
2. Engine compression brake (Jake Brake®)
3. Exhaust brake
4. Hydraulic engine retarder (BrakeSaver®)

_____ a. Alters exhaust valve operation to convert the engine into an energy-absorbing vacuum pump; places tremendous drag on the piston, slowing the vehicle

_____ b. Stops exhaust outflow, turning the engine into an energy-absorbing air compressor; produces drag on the pistons, slowing the vehicle

_____ c. Uses pressurized engine oil to produce drag inside a torque converter attached to the crankshaft

_____ d. Uses electromagnetic or hydraulic devices to create drag on the driveline, slowing the driving wheels

Objective 3

Select from the following list the advantages of engine brake and retarder systems by placing an "X" before each correct advantage.

_____ a. Improved vehicle productivity

_____ b. Reduced vehicle downtime

_____ c. Lower operating temperatures

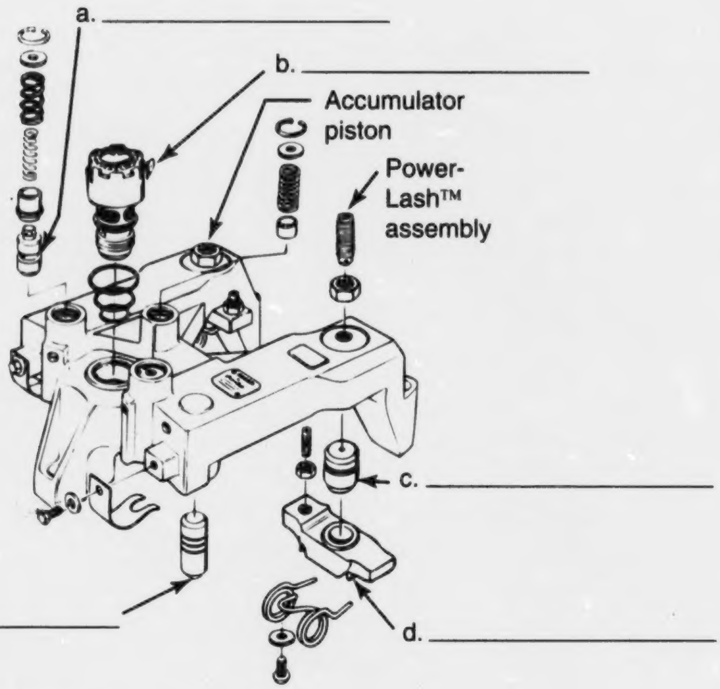
_____ d. Faster, steadier, more efficient braking performance

_____ e. Increased horsepower from existing injector pump settings

_____ f. Reduced wear on engine, tires, and foundation brakes

Objective 4

Label the following engine compression brake components on the illustration below.


a. ______________________
b. ______________________
Accumulator piston
Power-Lash™ assembly
c. ______________________
e. ______________________
d. ______________________

Courtesy of Jacobs Vehicle Systems

Objective 5

Match typical engine compression brake components with their correct functions. Write your answers in the blanks provided.

1. Electric control valve
2. Master piston
3. Slave piston
4. Solenoid valve

_____ a. Forces the exhaust rocker arm down, opening the exhaust valve(s) and releasing compression

_____ b. It opens, allowing oil to flow to both the slave piston and master piston

_____ c. Completes an electrical circuit, sending power to the engine brake solenoids

_____ d. Sends high pressure oil to the slave piston when the rocker arm adjusting screw moves upward

Written Test

Objective 6

Complete statements concerning engine operation with the engine compression brake energized by circling the correct answers.

a. Intake stroke—Intake valves (**open**, **close**) and air enters the cylinder.

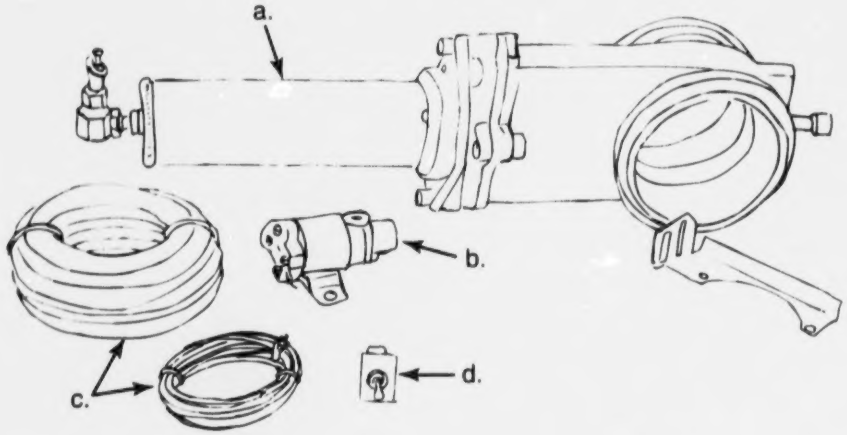
b. Compression stroke—Near TDC, the engine brake opens the (**intake**, **exhaust**) valves, venting high pressure air from the cylinder through the exhaust system.

c. Power stroke—As the piston moves (**up**, **down**), a strong vacuum is created.

d. Exhaust stroke—As the piston moves up, the exhaust valves (**open**, **close**).

Objective 7

Identify the exhaust brake components shown. Write your answers in the blanks provided.



Courtesy of Blue Ox Corporation

a. ______________________ c. ______________________

b. ______________________ d. ______________________

Objective 8

Match exhaust brake components with their correct functions. Write your answers in the blanks provided.

1. Air/vacuum supply line
2. Electric control switch
3. Exhaust brake
4. Solenoid valve

_____ a. Opens, allowing either air pressure or vacuum to the exhaust brake piston

_____ b. Internal piston closes a gate inside the exhaust brake housing

_____ c. Completes an electrical circuit, sending power to the air/vacuum solenoid valve

_____ d. Supplies the force to operate the exhaust brake

Objective 9

Complete statements concerning engine operation with the exhaust brake energized by labeling the strokes described below.

a. ______________________ stroke—Air is unable to exit the cylinder; the rising piston meets increasing resistance.

b. ______________________ stroke—No fuel is injected during closed throttle coasting, so no energy is produced.

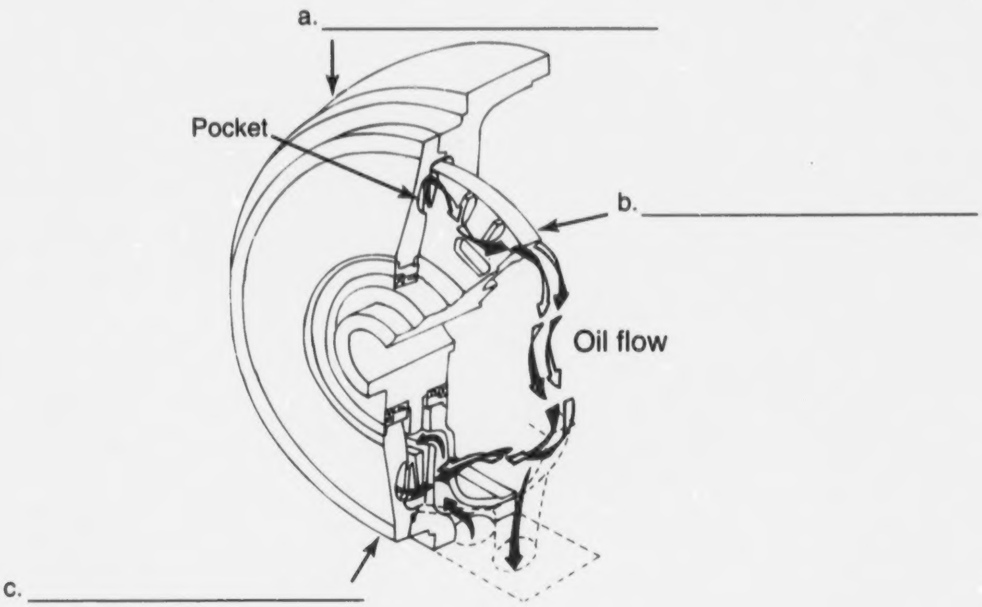
c. ______________________ stroke—Piston moves up, compressing the air, creating engine drag.

d. ______________________ stroke—Intake valves open and air enters the cylinder; complete cylinder filling is not possible.

Written Test

Objective 10

Label the hydraulic engine retarder components on the illustration below.



© Caterpillar Inc. Used with permission

Objective 11

Match hydraulic engine retarder components with their correct functions. Write your answers in the blanks provided.

1. Control valve
2. Housing
3. Rotor
4. Stator

_____ a. Fastened to the crankshaft, it turns in the hollow space between the housing and the stator

_____ b. Varies the amount of oil flow to the housing

_____ c. Bolted to the housing, it forms the back half of a hollow "doughnut"

_____ d. Mounts to the back of the engine block and contains the oil passages

Objective 12

Arrange in order the steps describing engine operation with the hydraulic engine retarder energized by placing the correct sequence numbers (1-4) in the appropriate blanks.

_____ a. The resistance of the oil between the vanes and pockets provides drag to the driveline and drive wheels.

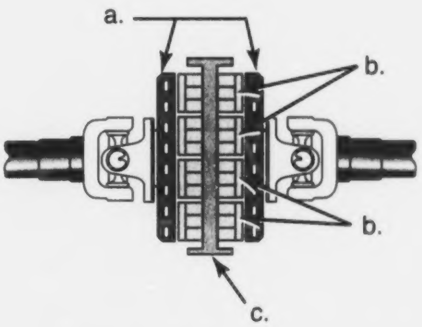
_____ b. Pressurized engine oil enters the housing at the bottom, begins surrounding the rotor, and fills the spaces between the stator and the housing.

_____ c. The vanes on the rotor constantly churn the oil, forcing it against the pockets in the stator and housing.

_____ d. The control valve allows oil to flow into the housing.

Objective 13

Identify electric driveline retarder components using the illustration and word bank below.



Courtesy of Jacobs Vehicle Systems

Coils
Electric control switch
Housing
Master piston
Rotors
Slave piston
Solenoid valve
Stator
Turbocharger

a. ______________________________

b. ______________________________

c. ______________________________

Written Test

Objective 14

Match electric driveline retarder components with their correct functions. Write your answers in the blanks provided.

1. Coils
2. Driver-operated rheostat
3. Rotors
4. Stator

_____ a. Vented, circular steel discs, mounted to the vehicle's driveline

_____ b. Contains the coils and is mounted to the vehicle chassis, transmission, or axle

_____ c. Create strong magnetic fields when current is passed through them

_____ d. Controls the amount of current flow to the retarder

Objective 15

Complete statements concerning engine operation with an electric driveline retarder energized by completing the statements below.

a. Vehicle operator activates a multi-position switch either by ____________________ control or through the ____________________ pedal.

b. ____________________ flows to the stator coils, setting up strong magnetic fields (eddy currents).

c. As the rotor passes through the magnetic fields, the eddy currents try to stop movement. This loss of motion generates great ____________________.

d. The ____________________ in the rotor force cool air over the coils, dissipating the buildup.

***Permission to duplicate this test is granted.**

Answers to Written Test

Objective 1

a. 2
b. 9
c. 5
d. 1
e. 4
f. 8
g. 10
h. 3

Objective 2

a. 2
b. 3
c. 4
d. 1

Objective 3

a, b, d, f

Objective 4

a. Control valve
b. Solenoid valve
c. Slave piston
d. Bridge
e. Master piston

Objective 5

a. 3
b. 4
c. 1
d. 2

Objective 6

a. Open
b. Exhaust
c. Down
d. Open

Objective 7

a. Exhaust brake
b. Solenoid valve
c. Air/vacuum supply lines
d. Electric control switch

Objective 8

a. 4
b. 3
c. 2
d. 1

Answers to Written Test

Objective 9	a. Exhaust
	b. Power
	c. Compression
	d. Intake
Objective 10	a. Housing
	b. Rotor
	c. Stator
Objective 11	a. 3
	b. 1
	c. 4
	d. 2
Objective 12	a. 4
	b. 2
	c. 3
	d. 1
Objective 13	a. Rotors
	b. Coils
	c. Stator
Objective 14	a. 3
	b. 4
	c. 1
	d. 2
Objective 15	a. Hand, brake
	b. Current
	c. Heat
	d. Vanes

Prerequisites:
None

Learning Activities Sheet

Student Name ______________________________

Place a checkmark in the appropriate box as you complete each of the steps below.

☐ 1. **Take** Pretest provided by instructor. After test has been evaluated, follow instructor's recommendations.

☐ 2. **Read** Objective Sheet.

☐ 3. **Study** Information Sheets, Objectives 1 through 6.

Optional

☐ 4. **Research** Online resources concerning Jacobs Engine brake system. Visit www.jakebrake.com as one of your sources.

☐ 5. **Observe** Demonstration of procedures to be used in completing Job Sheet 1.

☐ 6. **Do** Job Sheet 1, "Remove, Inspect, Install and Adjust a Jacobs Engine Brake".

☐ 7. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 8. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 1 and repeat steps 5 through 7.

☐ 8. **Study** Information Sheets, Objectives 7 through 9.

Optional

☐ 9. **View** Videotape entitled "Blue Ox Exhaust Brake Design, Operation, and Service".

☐ 10. **Observe** Demonstration of procedures to be used in completing Job Sheet 3.

☐ 11. **Do** Job Sheet 3, "Check Operation of an Exhaust Brake".

Learning Activities Sheet

☐ 12. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 13. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 3 and repeat steps 9 through 11.

☐ 13. **Observe** Demonstration of procedures to be used in completing Job Sheet 4.

☐ 14. **Do** Job Sheet 4, "Remove, Clean, and Reinstall an Exhaust Brake".

☐ 15. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 16. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 4 and repeat steps 13 through 15.

☐ 16. **Study** Information Sheets, Objectives 10 through 12.

☐ 17. **Observe** Demonstration of procedures to be used in completing Job Sheet 2.

☐ 18. **Do** Job Sheet 2, "Check Operation of a BrakeSaver®".

☐ 19. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 20. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 2 and repeat steps 16 through 18.

☐ 20. **Study** Information Sheets, Objectives 13 through 15.

Optional

☐ 21. **Research** Online resources concerning driveline retarder systems. Visit www.telma.com as one of your sources.

☐ 22. **Observe** Demonstration of procedures to be used in completing Job Sheet 5.

☐ 23. **Do** Job Sheet 5, "Check Operation of a Driveline Retarder".

☐ 24. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 25. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 5 and repeat steps 22 through 24.

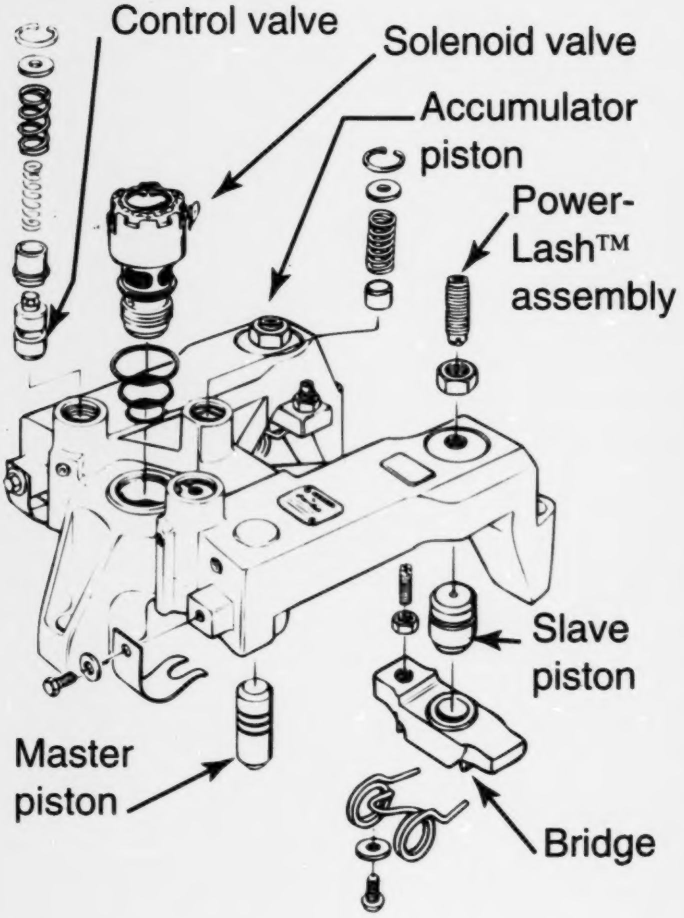
☐ 25. **Check** With instructor for any additional assignments to be completed.

☐ 26. **Take** Posttest provided by instructor. After test has been evaluated, follow instructor's recommendations.

☐ 27. **Stop** Have instructor evaluate your unit performance. If the evaluation is satisfactory, proceed to next learning activities sheet. If evaluation is not satisfactory, ask instructor for further instructions.

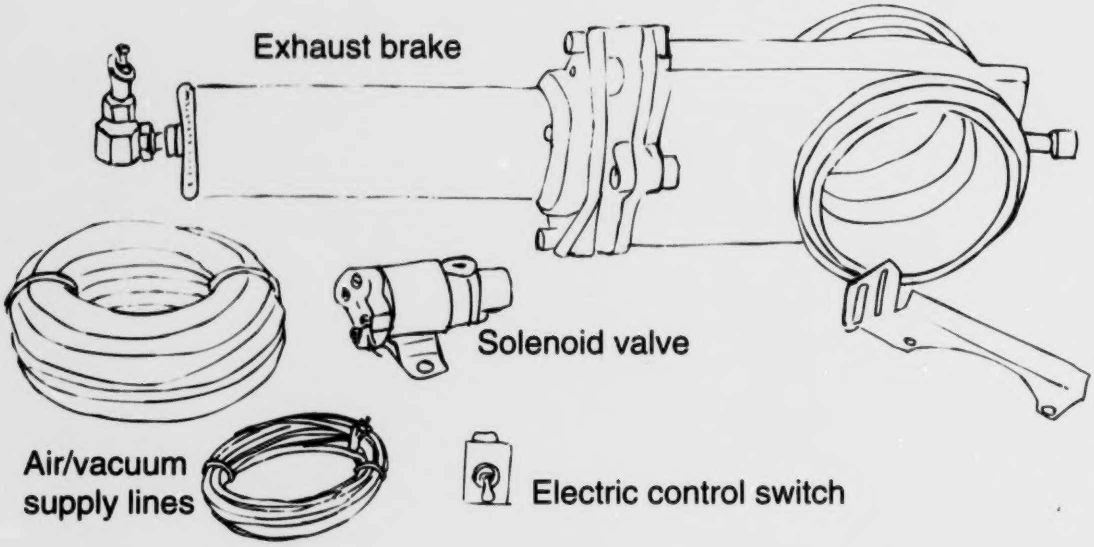
***Permission to duplicate this form is granted.**

Engine Compression Brake Components


Control valve
Solenoid valve
Accumulator piston
Power-Lash™ assembly
Slave piston
Master piston
Bridge

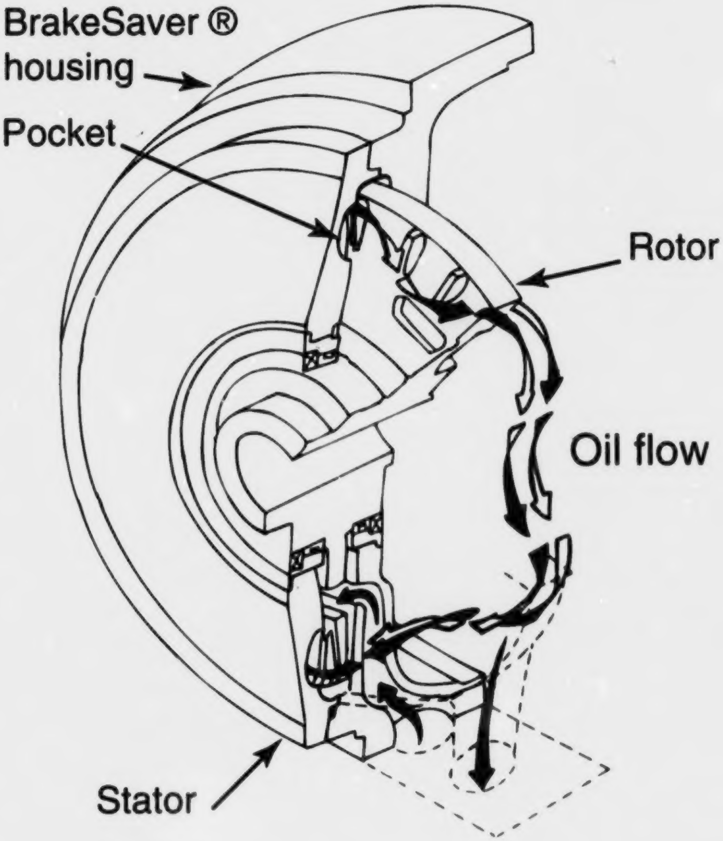
Courtesy of Jacobs Vehicle Systems

Exhaust Brake Components


Exhaust brake
Solenoid valve
Air/vacuum supply lines
Electric control switch

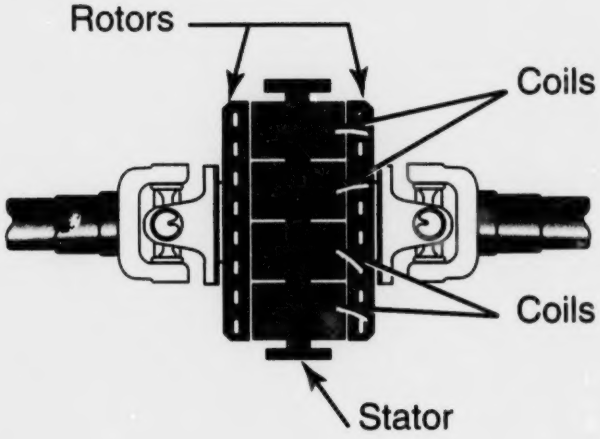
Courtesy of Blue Ox Corporation

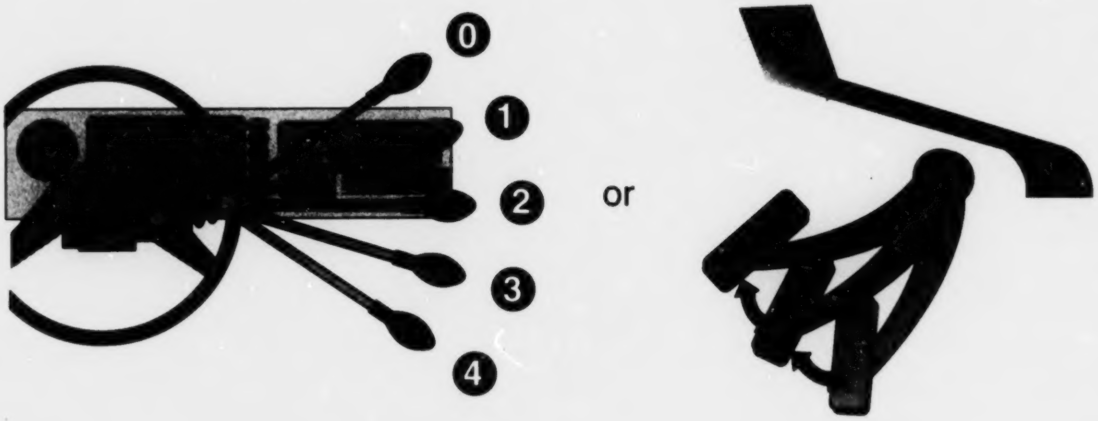
Hydraulic Engine Retarder Components (BrakeSaver®)


BrakeSaver ®
housing
Pocket
Rotor
Oil flow
Stator

© Caterpillar Inc. Used with permission

Electric Driveline Retarder Components


Rotors
Coils
Coils
Stator



Driver-Operated Rheostat

Courtesy of Jacobs Vehicle Systems

Unit 1-C Basic Fuel Systems and Components

Unit Contents

Teacher Components

Teacher Page

Suggested Activities 1C-3
Written Test 1C-11
Answers to Written Test 1C-19
Learning Activities Sheet 1C-23

Transparency Masters

1—Major Parts of a Fuel System 1C-25
2—Parts of Fuel Tanks 1C-27
3—Distributor-Type Pump Fuel System 1C-29
4—In-Line Pump Fuel System 1C-31
5—PT Pump Fuel System 1C-33
6—Unit Injector Fuel System 1C-35

Student Components

Student Page

Objective Sheet 1C-3
Information Sheet 1C-5

Assignment Sheet

1—Trace Fuel Flow Through Basic Fuel Systems 1C-19

Job Sheets

1—Check Fuel Level, Quality, and Consumption 1C-23
2—Inspect and Service Basic Fuel Supply Components 1C-27

Suggested Activities

Instructional Plan

Preparation

- Read the unit carefully and plan for instruction.
- Review "Teaching Suggestions." Plan for classroom activities.
- Plan your presentation to take advantage of student learning styles and to accommodate special-needs students.
- Prepare classroom. Put up posters and charts and display articles and other references related to this unit.
- Obtain films, videotapes, and other resources to supplement instruction of this unit. See "Resources Used in Developing This Unit" and "Suggested Supplemental Resources" for more information.
- For self-paced instruction, review Learning Activities Sheet. Modify as appropriate to include additional activities and/or resources available in your classroom. Make one copy for each student.
- Make transparencies from the transparency masters included in this unit. These appear in the teacher edition only.

Delivery and Application

Unit Introduction (self-paced instruction)

- Provide student with Learning Activities Sheet and unit of instruction.
- Review unit contents with student.
- Have the student complete the steps in the learning activities sheet.

Unit Introduction (group instruction)

- Provide students with unit of instruction.
- Discuss unit and specific objectives.
- Discuss the information sheet. Implement teaching plan to localize, supplement, and personalize the unit. Reinforce basic academic and workplace skills when applicable.
- Discuss the assignment sheet. Review with students the criteria for evaluation of these activities.

Suggested Activities

- Discuss and demonstrate the job sheets. Make sure all required tools, equipment, and materials are available. Review with students the criteria for evaluation of these activities and the rating scale that will be used to indicate job performance.

Teaching Suggestions

- Provide examples of assembled diesel engine equipment/vehicles so students can identify the parts of the fuel system. Provide students with heavyweight paper cards already labeled with the part names and have students tape the correct cards to the correct parts. This should help students see how all the parts work together.

- Show students individual examples of basic fuel system components including:

  — Fuel filters (primary and secondary)

  — Fuel pumps (injection and transfer) and primers

  — Fuel lines (high and low pressure) and fittings

  — Check, shutoff, and overflow valves

  — Injection nozzles and injectors

  — Mechanical and electronic controls

  Discuss their designs, operation, and basic functions. Allow students to handle the parts and become familiar with them.

- Have students identify the different types of fuel injection systems using vehicles and/or equipment available in the shop as outlined in Objective 8. Point out the advantages and disadvantages of each type and the most common applications.

- Use an actual fuel system on a vehicle available in the shop or a mock-up of a fuel system to show fuel system operation, especially the governor's operation. You may want to use cards with numbers so you can tape on the parts as you discuss the steps in the operation.

- Make a display of the different types of governors as outlined in Objective 13. Also discuss the different classes of governors outlined in Objective 14. Discuss their similarities and differences and their different applications.

- Discuss the most common problems that you have encountered with fuel injection systems. Also discuss how these problems affected the engine. Describe the preventive maintenance necessary to prevent expensive engine wear/failure problems. Stress the economic benefits of preventive maintenance.

- Show samples of fuel system parts that show excessive wear. Have students analyze and determine the root cause. (Thinking Skills—Problem Solving; Technology—Troubleshooting)

Evaluation

- Make copies of the written test. Add or modify test items as needed. The written test serves as both a pretest and posttest to assist in measuring each student's competency gains.

- Give and evaluate pretest. Modify lesson plan to include additional instruction for those areas where students were deficient.

- Evaluate the assignment sheets. Rate the student using the criteria listed on each assignment sheet. See Answers to Assignment Sheets for correct answers where applicable. If the student's performance is unacceptable, have the student review the appropriate materials and complete the assignment again.

- Evaluate the job sheets. When the student is ready to perform a specific task, obtain a copy of the job sheet which may be found in the student edition. Then observe the student performing the procedure.

  Process evaluation—Place a mark in the box to the left of each designated checkpoint if the student has satisfactorily completed the process step(s) for each checkpoint area. If the student is unable to complete the procedure correctly, have the student review the materials and try again.

  Product evaluation—Once the student has satisfactorily completed the procedure, rate the student product (outcome) using the criteria that are provided as part of the job sheet. If the student's product is unacceptable, have the student review the materials and submit another product for evaluation.

  Two sample performance evaluation keys have been provided below. Many other keys are available. Select one rating (grading scale) that best fits your program needs.

Sample A

4—**Skilled**—Can perform job with no additional training.
3—**Moderately skilled**—Has performed job during training program; limited additional training may be required.

Suggested Activities

2—**Limited skill**—Has performed job during training program; additional training is required to develop skill.
1—**Unskilled**—Is familiar with process, but is unable to perform job.
0—**No exposure**—No information or practice provided during training program.

Sample B

Yes—Can perform job with no additional training.
No—Is unable to perform job satisfactorily.

- Give and evaluate the posttest.
- Meet individually with students to evaluate their progress through this unit of instruction and indicate to them possible areas of improvement.
- Reteach and retest as required.

Resources Used in Developing This Unit

Print Media

- Clark, Elton, et al. *Diesel Fundamentals.* Stillwater, OK: Mid-America Vocational Curriculum Consortium, Inc., 1988.
- Dagel, John F. *Diesel Engine and Fuel System Repair*, 3rd ed. Upper Saddle River, NJ: Prentice Hall, 1994.
- Espenschied, Roland F. *Diesel Engines.* Athens, GA: American Association for Vocational Instructional Materials, 1990.

Suggested Supplemental Resources

Print Media

- *Oil Consumption Analysis.* (3387148). Available as booklet, slide set, or audio tape. Available from your local Cummins Engine Company dealer/distributor or call:

  Cummins Engine Company Customer Relations
  800-345-5654 or 502-453-8549 or for more information call 1-800-DIESELS

- *Diesel Injection Technology* reference book (200 pages). Covers a wide range of diesel topics including diesel engine, diesel fuel, emissions, injection technology, governors, nozzles, and starting aids.

  The above books is available from:

  Robert Bosch Corporation
  Training Materials
  2740 West 79th Street
  Chicago, IL 60652-1784
  Phone: 800-937-2672 or Fax: 312-776-1717

Suggested Activities

- Technical Instruction Booklets—Provide basic information and illustrations about system's components and operation. May also be available in German, French, and Spanish.
    - *Diesel Fuel Injection–An Overview* (1 987 722 104)
    - *Diesel Fuel Injection Pump Types PE and PF* (1 987 722 162)
    - *Governors for Inline Pumps* (1 987 722 163)
    - *Distributor Fuel Injection Pump Type VE* (1 987 722 164)
- Troubleshooting Guides—Help technicians diagnose problems quickly. Presents common faults, causes, and remedies. Plastic laminated.
    - *Diesel In-Line Pumps* (261202)
    - *VE Distributor Pump* (261201)
- Wall charts of diesel fuel injection pumps, governors, nozzle holders, and nozzles—Show cutaway views of common Bosch products. Available in small or large version.
    - *Type A Fuel Injection Pump*
    - *P Size Fuel Injection Pump*
    - *PES-MW Fuel Injection Pump*
    - *Mechanical Governor Type RQV*
    - *Mechanical Governor Type RQV-K*
    - *Mechanical Governor Types RSV*
    - *Distributor Type Fuel Injection Pump VE-F*
    - *Nozzle Holders and Nozzles*

The above are available from:

Robert Bosch Corporation
Training Materials
2740 West 79th Street
Chicago, IL 60652-1784
Phone: 800-937-2672 or Fax: 312-776-1717

- *ASE Test Prep Series*—Medium/Heavy Duty Truck, 2nd ed. (Diesel Engines). Albany, NY: Delmar Publishers, 2002.

  Also available in CD ROM format

- Bennett, Sean. *Medium/Heavy Duty Truck Engines, Fuel and Computerized Management Systems*. Albany, NY: Delmar Publishers, 1999.

- Bennett, Sean. *Today's Technician: Medium/Heavy Duty Truck Diesel Engines*. Albany, NY: Delmar Publishers, 2001.

- Brady, Robert. *Diesel Engine and Fuel System Repair*, 5th ed. Upper Saddle River, NJ: Prentice Hall Inc., 2002.

Electronic Media

- *3046 Engine–Introduction and Fuel System* (SESV1654), 40 slides. (1994) Available from your local CAT dealer or write the following for more information:

  Caterpillar Service Training
  600 W. Washington St., Bldg. JJ
  East Peoria, IL 61630

- Pump and Governor Programs—Training videos or slide sets that explain the theory of operation and servicing of selected Bosch diesel products. They include information on disassembly, inspection, reassembly, and calibration.

  — *A-Pump* video (STVV A) or slide/cassette (STSC A)

  — *MW-Pump* video (STVV MW) or slide/cassette (STSC MW)

  — *P-Pump* video (STVV P) or slide/cassette (STSC P)

  — *VE-Pump* video (STVV VE) or slide/cassette (STSC VE)

  — *RQV Governor* video (STVV RQV) or slide/cassette (STSC RQV)

  — *RQV-K Governor* video (STVV RQVK) or slide/cassette (STSC RQVK)

  — *RSV Governor* video (STVV RSV) or slide/cassette (STSC RSV)

  — *RW Governor* video (STVV RW) or slide/cassette (STSC RW)

  — *Nozzle Holders and Nozzles* video (STVV IN) or slide/cassette (STSC IN)

  The above are available from:

Robert Bosch Corporation
Training Materials
2740 West 79th Street
Chicago, IL 60652-1784
Phone: 800-937-2672 or Fax: 312-776-1717

- *Fuel System* VHS, 37 minutes

Provides instruction for the maintenance of a diesel engine fuel system. Includes: fuel line, changing the filter, bleeding the fuel valves, disassembly of an injector nozzle and testing.

The video listed above is available from:

NIMCO
P.O. Box 9
102 Hwy. 81 North
Calhoun, KY 42327-0009
Phone: 1-800-9626662
http://www.nimcoinc.com

Written Test

Name ______________________________

Date ______________________ Score __________

Objective 1

Match the terms with their definitions. Write the corresponding numbers on the blanks provided.

1. Atomize
2. Cetane number
3. Flash point
4. Governor
5. Ignition
6. Ignition delay
7. Injection
8. In-line
9. Misfiring injector
10. Nozzle
11. Prime
12. Purge
13. Restriction
14. Specific gravity
15. Unit fuel injector

_____ a. Method of forcing fuel into a chamber for combustion

_____ b. Combustion of fuel mixture in the combustion chamber

_____ c. To eliminate air in the fuel system by flushing with clean fuel

_____ d. When fuel is heated to a point where it gives off a flammable vapor

_____ e. Injector that fails to inject and atomize sufficient fuel to support combustion

_____ f. Having the parts arranged in a straight line

_____ g. Weight of a liquid or solid compared with the weight of an equal volume of water at 60°F

_____ h. To break down into small particles

_____ i. Device that controls engine speed under various load conditions by changing fuel delivery

_____ j. Period of time from injection to actual ignition

_____ k. Relative measure of the time delay between the beginning of fuel injection and the start of combustion

_____ l. Condition that reduces volume of fuel flow, but increases the pressure

_____ m. To completely fill the system with fuel oil

Written Test

Objective 2

List three major functions of fuel systems.

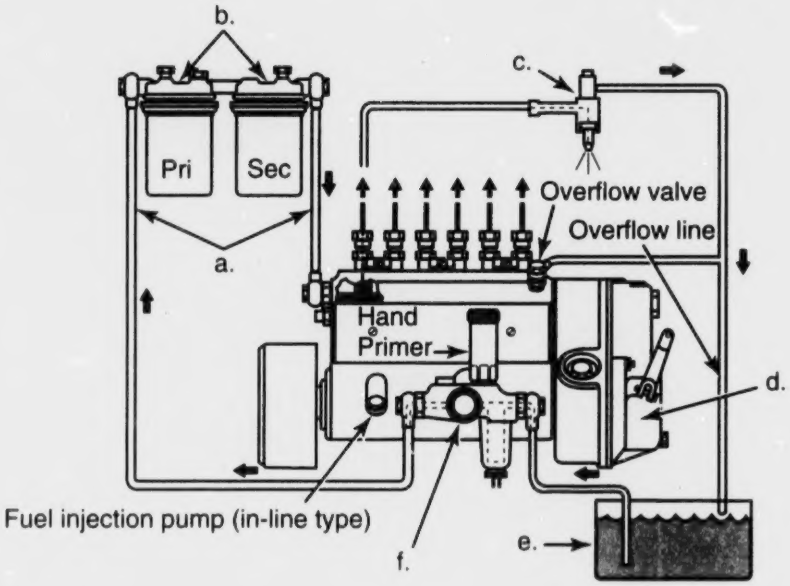
a. ______________________________

b. ______________________________

c. ______________________________

Objective 3

Identify the major parts of a fuel system. Write your answers in the blanks provided.


b.
c.
Pri
Sec
Overflow valve
Overflow line
a.
Hand
Primer
d.
Fuel injection pump (in-line type)
e.
f.

Courtesy of Robert Bosch Corporation

a. ____________________

b. ____________________

c. ____________________

d. ____________________

e. ____________________

f. ____________________

Objective 4

Match the parts of a fuel system with the correct functions. Write your answers in the blanks provided.

1. Fuel filters
2. Fuel heater
3. Fuel injection pump
4. Fuel lines
5. Fuel transfer pump
6. Governor
7. Injection nozzle
8. Primer or primer pump

_____ a. Moves fuel at low pressure from fuel tank to fuel injection pump

_____ b. Bleeds air from fuel system

_____ c. Times, measures, and delivers fuel under pressure to the injection nozzles

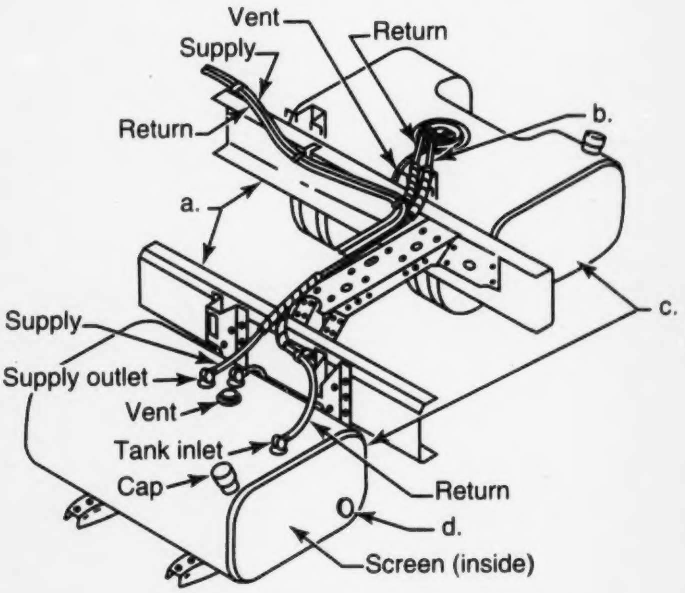
_____ d. Cleans the fuel by removing impurities

_____ e. Atomizes and distributes fuel evenly into the combustion chamber

_____ f. Controls the amount of fuel required to hold the engine speed reasonably constant during load fluctuations

Objective 5

Identify the parts of the fuel tanks. Write your answers in the blanks provided.



Courtesy of Navistar International Transportation Corp.

a. ____________________

b. ____________________

c. ____________________

d. ____________________

Written Test

Objective 6

List two types of fuel transfer pumps.

a. ______________________________

b. ______________________________

Objective 7

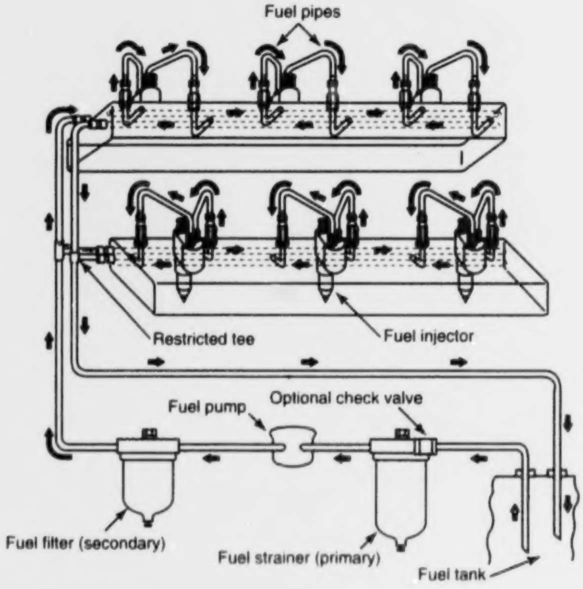
List two types of primer pumps according to how they are mounted.

a. ______________________________

b. ______________________________

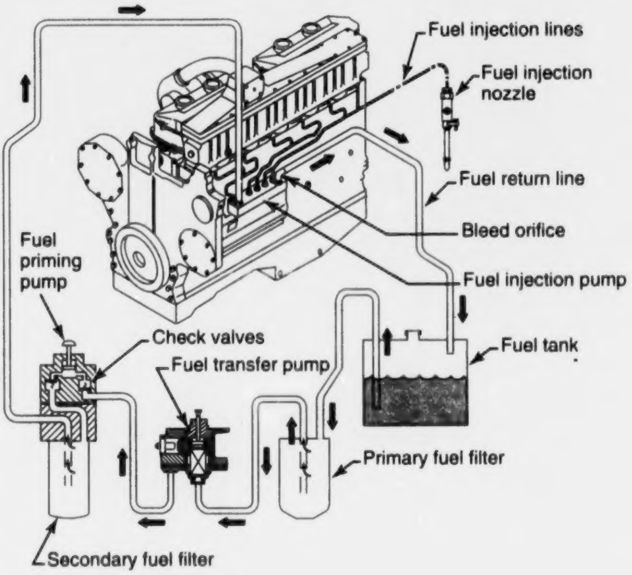
Objective 8

Identify the types of fuel injection systems shown below. Write your answers in the blanks provided.


Fuel pipes
Restricted tee
Fuel injector
Fuel pump
Optional check valve
Fuel filter (secondary)
Fuel strainer (primary)
Fuel tank

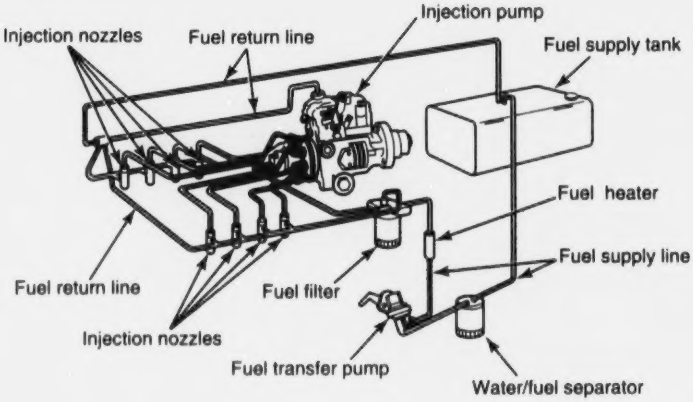
Courtesy of Detroit Diesel Corporation

a. ______________


Fuel injection lines
Fuel injection nozzle
Fuel return line
Bleed orifice
Fuel injection pump
Fuel priming pump
Check valves
Fuel transfer pump
Fuel tank
Primary fuel filter
Secondary fuel filter

© Caterpillar Inc. Used with permission

b. ______________________________


Injection pump
Injection nozzles
Fuel return line
Fuel supply tank
Fuel heater
Fuel supply line
Fuel return line
Fuel filter
Injection nozzles
Fuel transfer pump
Water/fuel separator

Courtesy of Ford Motor Company

c. ______________________________

Written Test

Objective 9

Distinguish between the methods of injecting fuel by placing an "I" next to descriptions of injectors and an "IN" next to descriptions of injector nozzles.

_____ a. Commonly used on in-line and distributor-type injection pumps

_____ b. Commonly used on PT injection pumps and unit injector systems

_____ c. Operated from the engine cam through a push rod and rocker arm

_____ d. Used in low pressure fuel systems

_____ e. Nozzle and pump are separated and connected with a high pressure line.

_____ f. May be unit injectors or mechanical injectors.

Objective 10

Describe the types of controls on fuel systems.

a. Mechanical

____

____

____

b. Electronic

____

____

____

____

Objective 11

Match types of fuel lines with the correct functions. Write your answers in the blanks provided.

1. Return low pressure lines
2. Schedule 80 high pressure lines
3. Supply low pressure lines

_____ a. Delivers fuel from tank to fuel injection pump

_____ b. Delivers fuel from in-line or distributor-type pump to injection nozzles

_____ c. Delivers leak-off fuel from injection nozzles to tank

Objective 12

Distinguish between types of fuel filters by placing a "P" next to primary filters and an "S" next to secondary filters.

_____ a. Filters out initial impurities such as dirt particles and insoluble gums in the fuel

_____ b. Is located on the pressure side of the transfer pump

_____ c. Sometimes has a water separator with drain at the bottom

_____ d. Is located on the suction side of the transfer pump

_____ e. Has little resistance to flow

_____ f. Usually is the final filter

Objective 13

Match types of governors with their descriptions. Write your answers in the blanks provided.

1. Electric/electronic governor
2. Hydraulic governor
3. Mechanical governor
4. Pneumatic governor

_____ a. Uses flyweights to move the fuel control device which changes the engine speed

_____ b. Uses oil pressure or fuel pressure and mechanical weights to move metering valve or control rack

_____ c. Uses a vacuum created by air pressure differences to move the fuel control and change engine speed

_____ d. Uses electronic sensors to detect engine speed changes which results in new signals to change throttle position; typically used on stationary engines such as generators

Objective 14

Distinguish among classes of governors by placing an "X" next to the description of a limiting speed governor.

_____ a. Restricts maximum speed of the engine and controls engine idling speed; used on engines requiring minimum and maximum speed control, together with manually controlled intermediate speeds

_____ b. Controls engine idle speed, restricts maximum no-load speed, and holds the engine at any constant speed (between idle and maximum) as desired by the vehicle operator; used on engines subjected to varying load conditions that require an automatic fuel compensation to maintain a near constant engine speed, which may be changed manually by the operator; commonly used for construction and agriculture applications

_____ c. Maintains engine speed at constant rpm; used on stationary engines such as generators

Written Test

Objective 15

Arrange in order the steps in the operation of the mechanical governor by placing the correct sequence numbers (1–3) in the appropriate blanks.

_____ a. The throttle shaft moves the governor spring and linkage to open the metering valve or move the control rack.

_____ b. After engine speed responds (more fuel is delivered so engine speeds up), centrifugal force on the governor weights moves them outward which compresses the governor spring and cuts back fuel delivery. Compressed governor spring linkage now limits maximum speed of engine.

_____ c. When more vehicle speed is desired, the operator's foot moves the foot feed which is connected through linkage (cable or rod) to the pump's throttle shaft.

Objective 16

Select from the following list the common maintenance problems on fuel systems by placing an "X" in the appropriate blanks.

_____ a. Fuel line restrictions

_____ b. Hard steering

_____ c. Hard starting

_____ d. Shimmy

_____ e. Excessive fuel consumption

_____ f. Loss of electrical power

_____ g. Clogged filters

_____ h. Leaking lines

_____ i. Tank problems—Leaks, water, dirt, or clogged vent

Objective 17

List seven factors that affect fuel consumption.

a. ____

b. ____

c. ____

d. ____

e. ____

f. ____

g. ____

***Permission to duplicate this test is granted.**

Answers to Written Test

Objective 1

a. 7
b. 5
c. 12
d. 3
e. 9
f. 8
g. 14
h. 1
i. 4
j. 6
k. 2
l. 13
m. 11

Objective 2

Any three of the following:

a. Supplies the correct quantity of fuel
b. Times the fuel delivery
c. Controls the delivery rate
d. Atomizes the fuel
e. Distributes the fuel evenly throughout the combustion chamber

Objective 3

a. Fuel lines
b. Fuel filters
c. Injection nozzle
d. Governor
e. Fuel tank
f. Fuel transfer pump

Objective 4

a. 5
b. 8
c. 3
d. 1
e. 7
f. 6

Objective 5

a. Mounting brackets
b. Supply (line)
c. Tank housings
d. Drain

Objective 6

Any two of the following:

a. Piston type
b. Diaphragm type
c. Gear type or rotary
d. Electric vane type

Objective 7

Any two of the following:

a. Mounted on primary filter
b. Mounted on piston type fuel transfer pump
c. Mounted in-line

Answers to Written Test

Objective 8

a. Unit injector
b. In-line pump
c. Distributor-type pump

Objective 9

a. IN
b. I
c. I
d. I
e. IN
f. I

Objective 10

Answers should include the following in student's own words:

a. Mechanical
  - Uses governor flyweights to control amount of fuel delivered to injection nozzles or injectors (PT)
  - Unit injectors use mechanical governor through linkage to control amount of fuel that injection delivers.

b. Electronic
  - Uses electric solenoids and electronic control modules (ECM) to control and govern the amount of fuel delivered to the unit injector
  - In-line and distributor pumps can have electronic governors mounted on the pump to control the fuel.
  - PT systems may also use electronic device on top of pump to control fuel to injectors.
  - Electro-hydraulic systems use engine oil raised to high pressure to the injector unit which is controlled by electronic solenoid and ECM.

Objective 11

a. 3
b. 2
c. 1

Objective 12

a. P
b. S
c. P
d. P
e. P
f. S

Objective 13

a. 3
b. 2
c. 4
d. 1

Objective 14

a

Objective 15

a. 2
b. 3
c. 1

Objective 16

a, c, e, g, h, i

Objective 17

Any seven of the following:

a. Road conditions—Gravel, bumpy, smooth, etc.
b. Weather conditions—Rain, snow, windy, extremely high or low temperatures, etc.
c. Gross vehicle weight—Vehicle + payload
d. Road speed
e. Idle time
f. Amount of time cruising vs. changing gears and speeds
g. Type of tires
h. Wind drag
i. Axle alignment
j. Fuel system leaks
k. Brake drag
l. Fuel rate, pressure, or temperature
m. Fuel system restrictions—inlet, drain, vent
n. Air inlet or exhaust restrictions
o. Fuel temperature

Prerequisites:
None

Learning Activities Sheet

Student Name ______________________________

Place a checkmark in the appropriate box as you complete each of the steps below.

☐ 1. **Take** Pretest provided by instructor. After test has been evaluated, follow instructor's recommendations.

☐ 2. **Read** Objective Sheet.

☐ 3. **Study** Information Sheet, Objectives 1 through 6.

☐ 4. **Do** Assignment Sheet 1, "Trace Fuel Flow Through Basic Fuel Systems".

☐ 5. **Stop** Have instructor evaluate the completed assignment sheet and if the evaluation is satisfactory, continue to step 6. If the evaluation is not satisfactory, repeat steps 3 and 4.

☐ 6. **Study** Information Sheet, Objectives 9 through 17.

Optional

☐ 7. **View** Videotape entitled "Fuel System".

☐ 8. **Observe** Demonstration of procedures to be used in completing Job Sheet 1.

☐ 9. **Do** Job Sheet 1, "Check Fuel Level, Quality, and Consumption".

☐ 10. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to Step 11. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 1 and repeat steps 8 through 10.

☐ 11. **Observe** Demonstration of procedures to be used in completing Job Sheet 2.

☐ 12. **Do** Job Sheet 1, "Inspect and Service Basic Fuel Supply Components".

☐ 13. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to Step 14. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 2 and repeat steps 11 through 13.

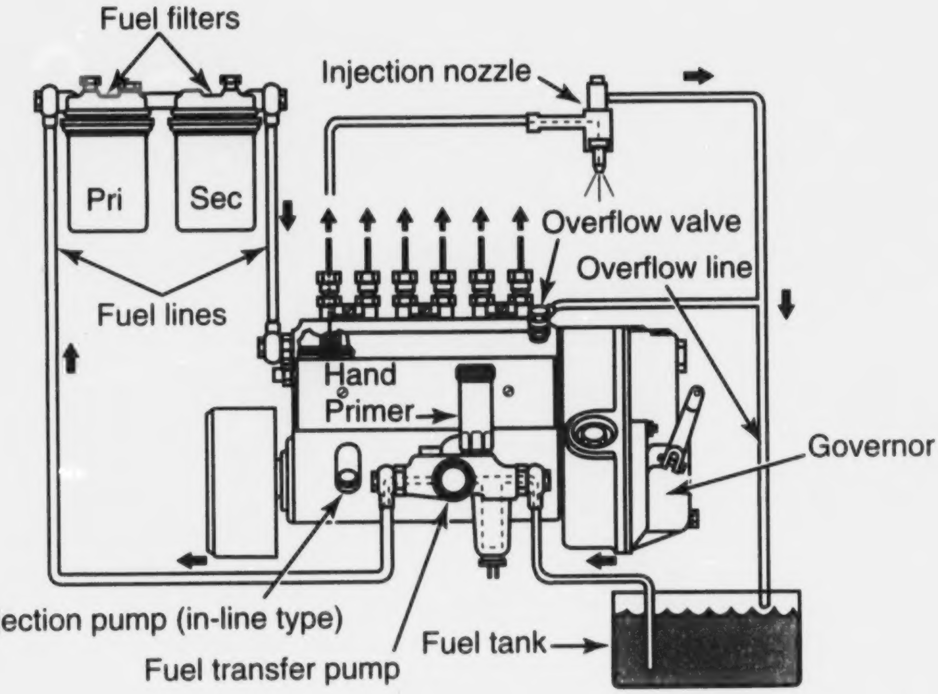
☐ 14. **Check** With instructor for any additional assignments to be completed.

☐ 15. **Take** Posttest provided by instructor. After test has been evaluated, follow instructor's recommendations.

☐ 16. **Stop** Have instructor evaluate your unit performance. If the evaluation is satisfactory, proceed to next learning activities sheet. If evaluation is not satisfactory, ask instructor for further instructions.

***Permission to duplicate this form is granted.**

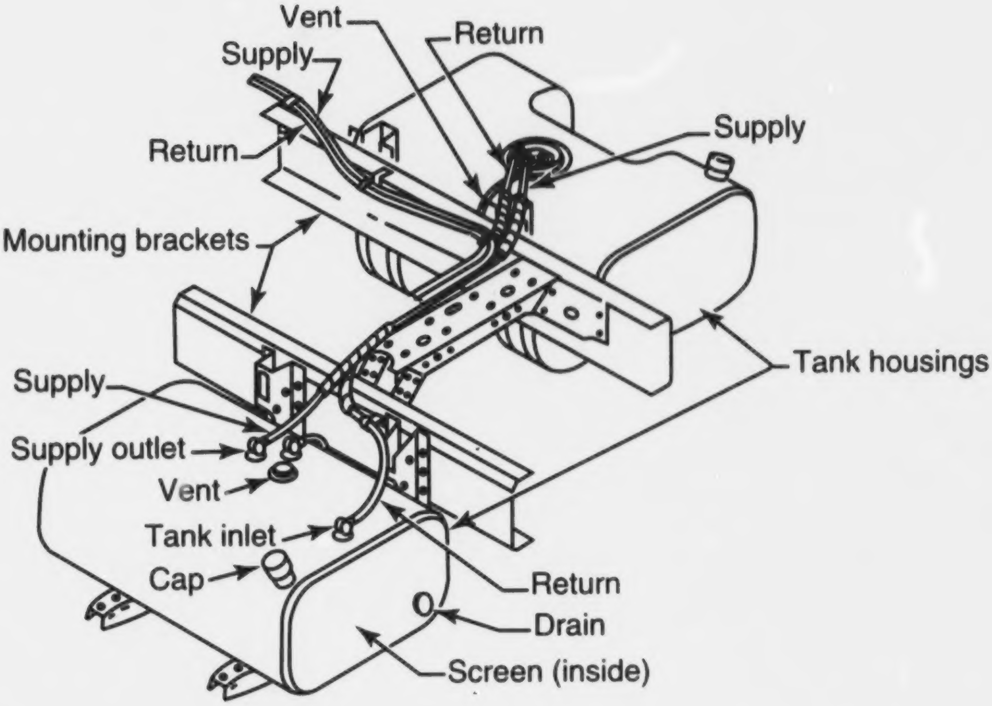
Major Parts of a Fuel System


Fuel filters
Injection nozzle
Pri
Sec
Overflow valve
Overflow line
Fuel lines
Hand Primer
Governor
Fuel injection pump (in-line type)
Fuel tank
Fuel transfer pump

Courtesy of Robert Bosch Corporation

TM 1

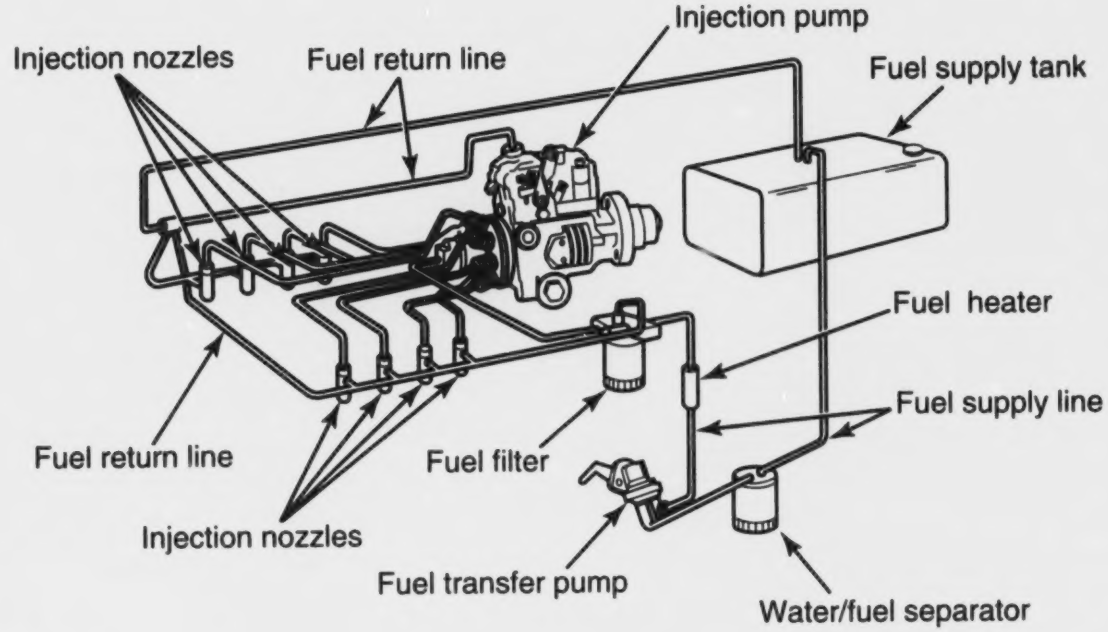
Parts of Fuel Tanks


Vent
Return
Supply
Supply
Return
Mounting brackets
Tank housings
Supply
Supply outlet
Vent
Tank inlet
Cap
Return
Drain
Screen (inside)

Courtesy of Navistar International Transportation Corp.

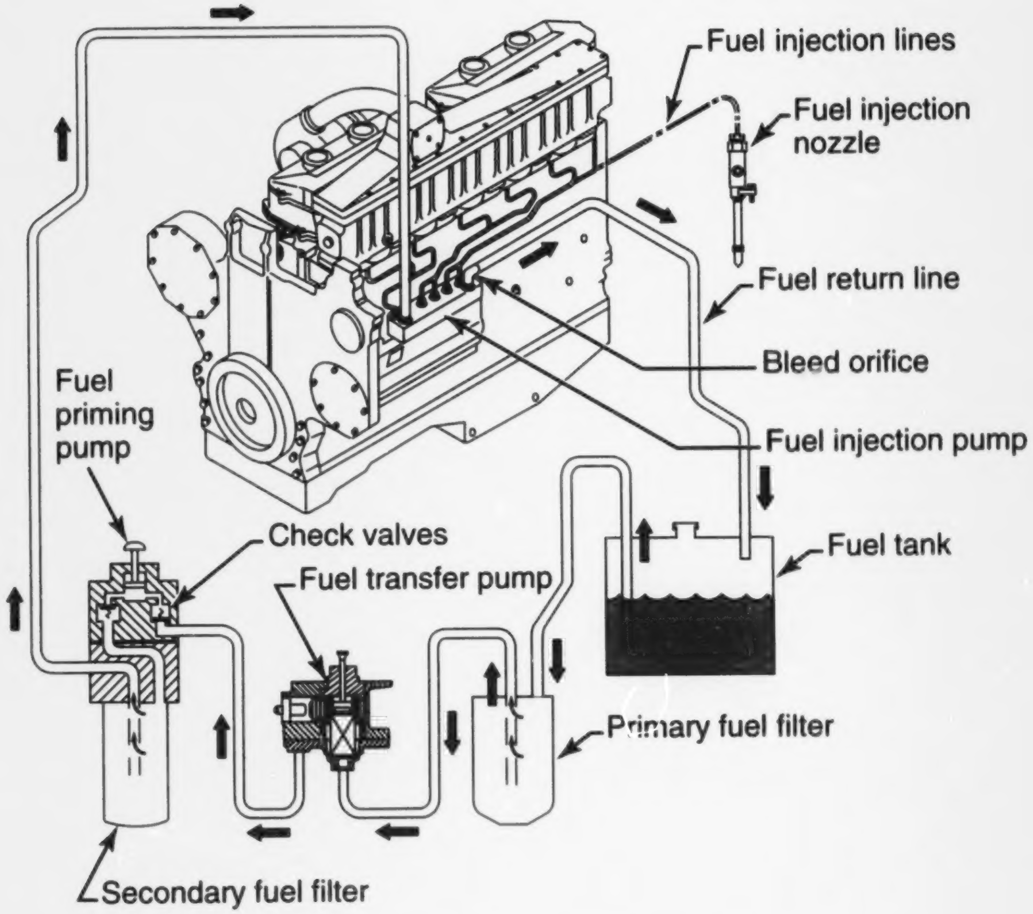
TM 2

Distributor-Type Pump Fuel System


Injection nozzles
Fuel return line
Injection pump
Fuel supply tank
Fuel heater
Fuel supply line
Fuel return line
Fuel filter
Injection nozzles
Fuel transfer pump
Water/fuel separator

Reprinted with permission of Ford Motor Company

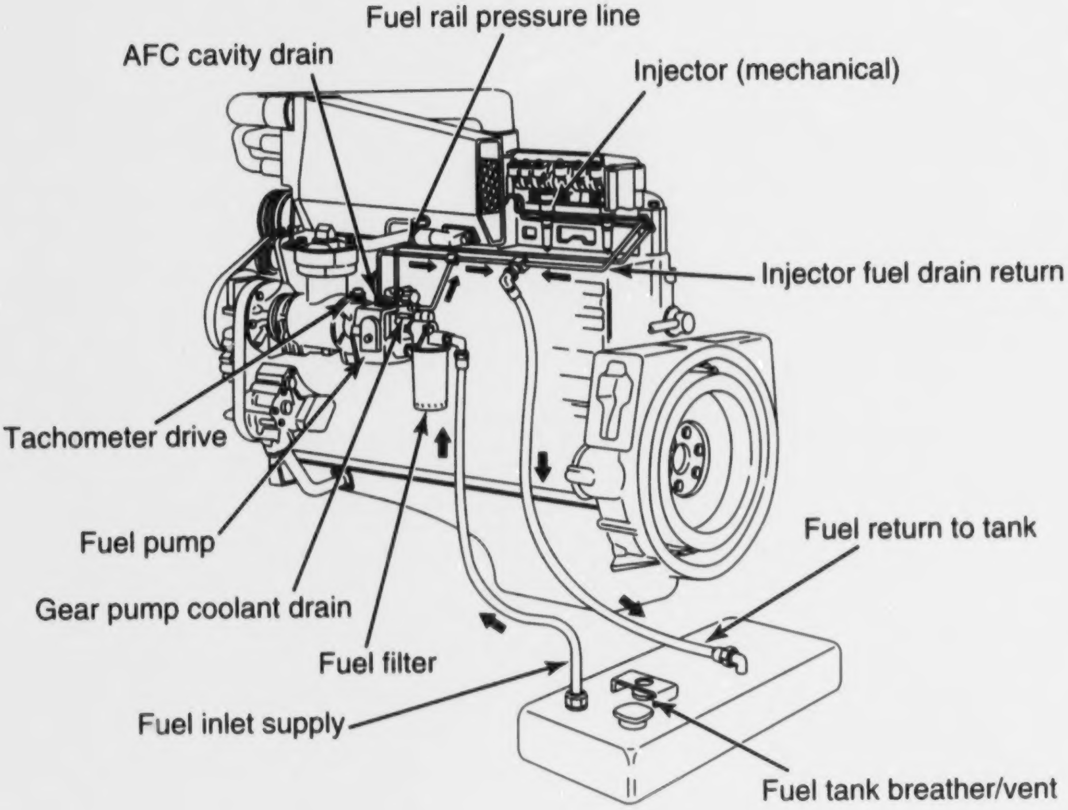
In-Line Pump Fuel System


Fuel injection lines
Fuel injection nozzle
Fuel return line
Bleed orifice
Fuel injection pump
Fuel priming pump
Check valves
Fuel transfer pump
Fuel tank
Primary fuel filter
Secondary fuel filter

© Caterpillar Inc. Used with permission

TM 4

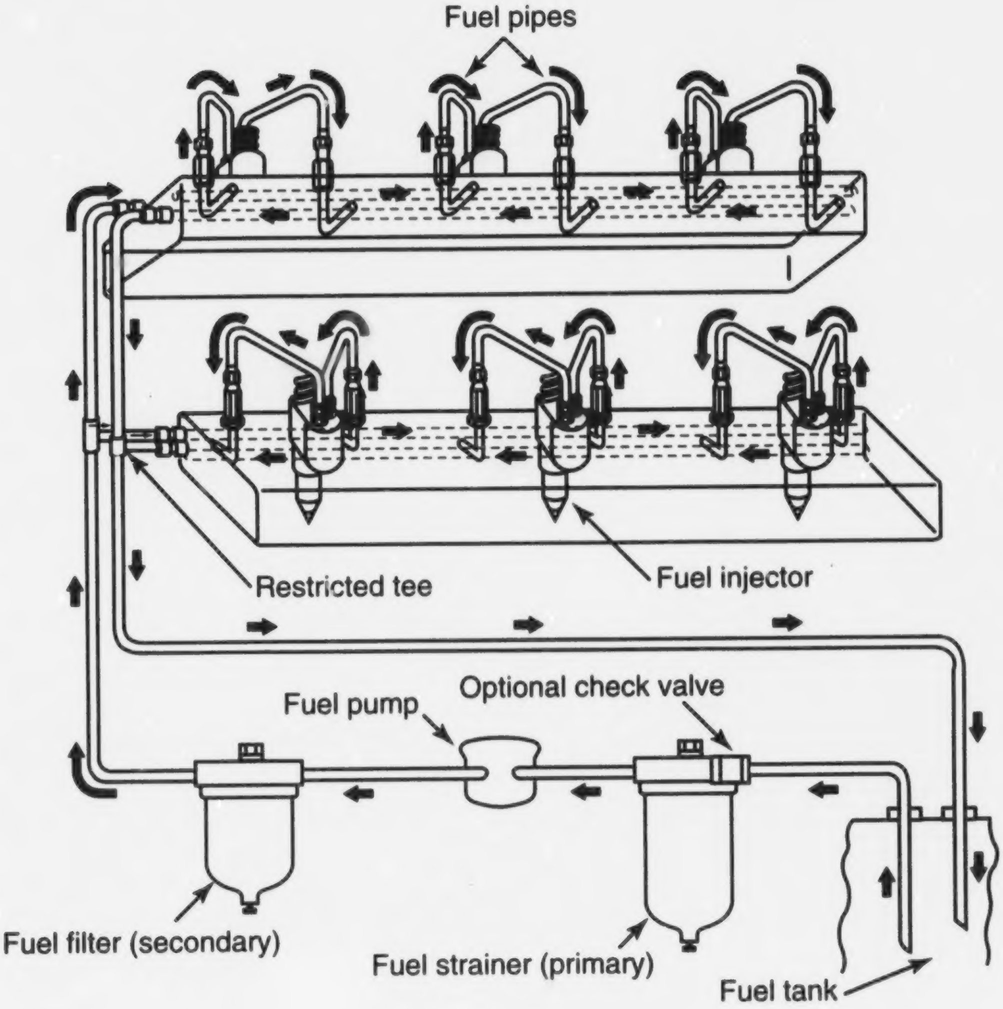
PT Pump Fuel System


Fuel rail pressure line
AFC cavity drain
Injector (mechanical)
Injector fuel drain return
Tachometer drive
Fuel pump
Fuel return to tank
Gear pump coolant drain
Fuel filter
Fuel inlet supply
Fuel tank breather/vent

Courtesy of Cummins Engine Company, Inc.

TM 5

Unit Injector Fuel System


Fuel pipes
Restricted tee
Fuel injector
Fuel pump
Optional check valve
Fuel filter (secondary)
Fuel strainer (primary)
Fuel tank

Courtesy of Detroit Diesel Corporation

Mechanical Fuel Injection Diagnosis and Repair

Unit Contents

Teacher Components

Teacher Page

Suggested Activities 2C-3
Written Test 2C-9
Answers to Written Test 2C-23
Learning Activities Sheet 2C-27

Transparency Masters

1—Parts of Injection Nozzles 2C-31
2—Types of Nozzle Valves 2C-33
3—Parts of a Mechanical Unit Injector 2C-35
4—Parts of a Distributor-Type Injection Pump 2C-37
5—Main Parts of an In-Line Injection Pump 2C-39
6—Pump Details 2C-41
7—Plunger and Rack Positions 2C-43
8—Main Parts of a PT Injection Pump 2C-45
9—Operation of PT Injectors 2C-47

Student Components

Student Page

Objective Sheet 2C-3
Information Sheet 2C-5

Job Sheets

1—Isolate, Remove, Test, Rebuild or Replace, and Reinstall Injection Nozzles 2C-21
2—Isolate, Remove, Test, and Reinstall or Replace Mechanical Unit Injectors 2C-25
3—Inspect, Test, Adjust, and Time a Distributor-Type (Rotary) Injection Pump; Determine Needed Repairs 2C-29
4—Inspect, Test, Adjust, and Time an In-line Injection Pump; Determine Needed Repairs 2C-33
5—Inspect, Test, and Adjust a PT Injection Pump and Time the Injectors; Determine Needed Repairs 2C-37

Suggested Activities

Instructional Plan

Preparation

- Read the unit carefully and plan for instruction.
- Review "Teaching Suggestions." Plan for classroom activities.
- Plan your presentation to take advantage of student learning styles and to accommodate special-needs students.
- Prepare classroom. Put up posters and charts and display articles and other references related to this unit.
- Obtain films, videotapes, and other resources to supplement instruction of this unit. See "Resources Used in Developing This Unit" and "Suggested Supplemental Resources" for more information.
- For self-paced instruction, review Learning Activities Sheet. Modify as appropriate to include additional activities and/or resources available in your classroom. Make one copy for each student.
- Make transparencies from the transparency masters included in this unit. These appear in the teacher edition only.

Delivery and Application

Unit Introduction (self-paced instruction)

- Provide student with Learning Activities Sheet and unit of instruction.
- Review unit contents with student.
- Have the student complete the steps in the learning activities sheet.

Unit Introduction (group instruction)

- Provide students with unit of instruction.
- Discuss unit and specific objectives.
- Discuss the information sheet. Implement teaching plan to localize, supplement, and personalize the unit. Reinforce basic academic and workplace skills when applicable.

Suggested Activities

- Discuss and demonstrate the job sheets. Make sure all required tools, equipment, and materials are available. Review with students the criteria for evaluation of these activities and the rating scale that will be used to indicate job performance.

Teaching Suggestions

- Make a display of many different types of injection nozzles and mechanical unit injectors. Have students identify the parts. Also discuss the parts that require regular maintenance.
- Provide examples of diesel engines with different types of mechanical fuel injection systems so students can distinguish between the types. Include the following systems:
    - Distributor-type injection pump system
    - In-line injection pump system
    - PT injection pump system

  Discuss the similarities and differences between the types.
- Provide examples of mechanical fuel injection pumps so students can identify the parts. Also discuss the parts that require regular maintenance.
- Construct a mock-up of a partially disassembled and/or cutaway fuel injection pump so students can see the parts, design features, and operation as the plunger and rack move to deliver fuel.
- Show examples of different types of PT injectors, and discuss the most common types.

Evaluation

- Make copies of the written test. Add or modify test items as needed. The written test serves as both a pretest and posttest to assist in measuring each student's competency gains.
- Give and evaluate pretest. Modify lesson plan to include additional instruction for those areas where students were deficient.
- Evaluate the job sheets. When the student is ready to perform a specific task, obtain a copy of the job sheet which may be found in the student edition. Then observe the student performing the procedure.

Process evaluation—Place a mark in the box to the left of each designated checkpoint if the student has satisfactorily completed the process step(s) for each checkpoint area. If the student is unable to complete the procedure correctly, have the student review the materials and try again.

Product evaluation—Once the student has satisfactorily completed the procedure, rate the student product (outcome) using the criteria that are provided as part of the job sheet. If the student's product is unacceptable, have the student review the materials and submit another product for evaluation.

Two sample performance evaluation keys have been provided below. Many other keys are available. Select one rating (grading scale) that best fits your program needs.

Sample A

4—**Skilled**—Can perform job with no additional training.
3—**Moderately skilled**—Has performed job during training program; limited additional training may be required.
2—**Limited skill**—Has performed job during training program; additional training is required to develop skill.
1—**Unskilled**—Is familiar with process, but is unable to perform job.
0—**No exposure**—No information or practice provided during training program.

Sample B

Yes—Can perform job with no additional training.
No—Is unable to perform job satisfactorily.

- Give and evaluate the posttest.
- Meet individually with students to evaluate their progress through this unit of instruction and indicate to them possible areas of improvement.
- Reteach and retest as required.

Resources Used in Developing This Unit

Print Media

- Clark, Elton, et al. *Diesel Fundamentals.* Stillwater, OK: Mid-America Vocational Curriculum Consortium, Inc., 1988.
- Dagel, John F. *Diesel Engine and Fuel System Repair*, 3rd ed. Upper Saddle River, NJ: Prentice Hall, 1994.
- Espenschied, Roland F. *Diesel Engines.* Athens, GA: American Association for Vocational Instructional Materials, 1990.

Suggested Activities

Suggested Supplemental Resources

Print Media

- *ASE Test Prep Series*—Medium/Heavy Duty Truck, 2nd ed. (Diesel Engines). Albany, NY: Delmar Publishers, 2002.

  Also available in CD ROM format

- Bennett, Sean. *Medium/Heavy Duty Truck Engines, Fuel and Computerized Management Systems*. Albany, NY: Delmar Publishers, 1999.

- Bennett, Sean. *Today's Technician: Medium/Heavy Duty Truck Diesel Engines*. Albany, NY: Delmar Publishers, 2001.

- Brady, Robert. *Diesel Engine and Fuel System Repair*, 5th ed. Upper Saddle River, NJ: Prentice Hall inc., 2002.

- *Injection Timing* (3387199). Available as booklet, slide set, or audio tape.

- *Injector and Valve Adjustment*. (3387237). Available as booklet, slide set, or audio tape.

  The above are available from your local Cummins Engine Company dealer/distributor or call:

  Cummins Engine Company Customer Relations
  800-345-5654 or 502-453-8549 or for more information call 1-800-DIESELS

- *Diesel Injection Technology* reference book (200 pages). Covers a wide range of diesel topics including diesel engine, diesel fuel, emissions, injection technology, governors, nozzles, and starting aids.

- Technical Instruction Booklets—Provide basic information and illustrations about system's components and operation. May also be available in German, French, and Spanish.

  — *Diesel Fuel Injection–An Overview* (1 987 722 104)

  — *Diesel Fuel Injection Pump Types PE and PF* (1 987 722 162)

  — *Governors for Inline Pumps* (1 987 722 163)

  — *Distributor Fuel Injection Pump Type VE* (1 987 722 164)

- Troubleshooting Guides—Help technicians diagnose problems quickly. Presents common faults, causes, and remedies. Plastic laminated.

  — *Diesel In-Line Pumps* (261202)

  - *VE Distributor Pump* (261201)

- Wall charts of diesel fuel injection pumps, governors, nozzle holders, and nozzles—Show cutaway views of common Bosch products. Available in small or large version.

  - *Type A Fuel Injection Pump*
  - *P Size Fuel Injection Pump*
  - *PES-MW Fuel Injection Pump*
  - *Mechanical Governor Type RQV*
  - *Mechanical Governor Type RQV-K*
  - *Mechanical Governor Types RSV*
  - *Distributor Type Fuel Injection Pump VE-F*
  - *Nozzle Holders and Nozzles*

  The above are available from:

  Robert Bosch Corporation
  Training Materials
  2740 West 79th Street
  Chicago, IL 60652-1784
  Phone: 800-937-2672 or Fax: 312-776-1717

Electronic Media

- *Fuel System*, VHS, 37 minutes

  Provides instruction for the maintenance of a diesel engine fuel system. Includes: fuel line, changing the filter, bleeding the fuel valves, disassembly of an injector nozzle and testing.

- *Diesel Injection System Service*, VHS, 27 minutes

  Uses live action footage and computer animation to explain various types of diesel injection systems.

  The above are available from:

  NIMCO
  P.O. Box 9
  102 Hwy. 81 N.
  Calhoun, KY 42327-0009
  1-800-962-6662
  www.nimcoinc.com

Suggested Activities

- *Fuel injection System, Part 1 Kit,* (6-399K). Includes video and five guide books.
- *Fuel Injection System, Part 2 Kit,* (6-398K). Includes video and five guide books.

The above are available from:

Mack Trucks, Inc.
2100 Mack Boulevard
P.O. Box M
Allentown, PA 18195-5000
610-439-3011

- Pump and Governor Programs—Training videos or slide sets that explain the theory of operation and servicing of selected Bosch diesel products. They include information on disassembly, inspection, reassembly, and calibration.
  - *A-Pump* video (STVV A) or slide/cassette (STSC A)
  - *MW-Pump* video (STVV MW) or slide/cassette (STSC MW)
  - *P-Pump* video (STVV P) or slide/cassette (STSC P)
  - *VE-Pump* video (STVV VE) or slide/cassette (STSC VE)
  - *RQV Governor* video (STVV RQV) or slide/cassette (STSC RQV)
  - *RQV-K Governor* video (STVV RQVK) or slide/cassette (STSC RQVK)
  - *RSV Governor* video (STVV RSV) or slide/cassette (STSC RSV)
  - *RW Governor* video (STVV RW) or slide/cassette (STSC RW)
  - *Nozzle Holders and Nozzles* video (STVV IN) or slide/cassette (STSC IN)

The above is available from:

Robert Bosch Corporation
Training Materials
2740 West 79th Street
Chicago, IL 60652-1784
Phone: 800-937-2672 or Fax: 312-776-1717

Written Test

Name ____

Date ______________________________ Score___________

Objective 1

Match the terms with their definitions. Write the correct answers in the blanks provided.

1. Aneroid
2. Annular groove
3. Circuit
4. Delivery valve
5. Helix
6. Gallery
7. Governor
8. Hydraulic
9. Metering
10. Orifice
11. Pintle
12. Registry
13. Retraction
14. Servomechanism
15. Spray tip orifices

_____ a. Complete path of fuel flow

_____ b. Spiraled, machined recess on pumping plunger

_____ c. Small hole

_____ d. Smoke limiting device

_____ e. Long, narrow fuel or oil passage

_____ f. Automatic device for controlling large amounts of power with small amounts of power as a piston moved by fluid under pressure

_____ g. A speed-sensing device that employs centrifugal force and spring tension to govern the engine speed

_____ h. Valve in which the end extends into a shank or pin

_____ i. Type of valve that provides retraction of delivery line pressure causing nozzle valve to return to its seat, thereby preventing dribble of fuel into combustion chamber

_____ j. Machined recess forming a ring on pumping plunger

_____ k. Holes through the wall at the end of the tip which allow fuel to be sprayed into the combustion chamber

_____ l. Precision measurement of fuel delivery

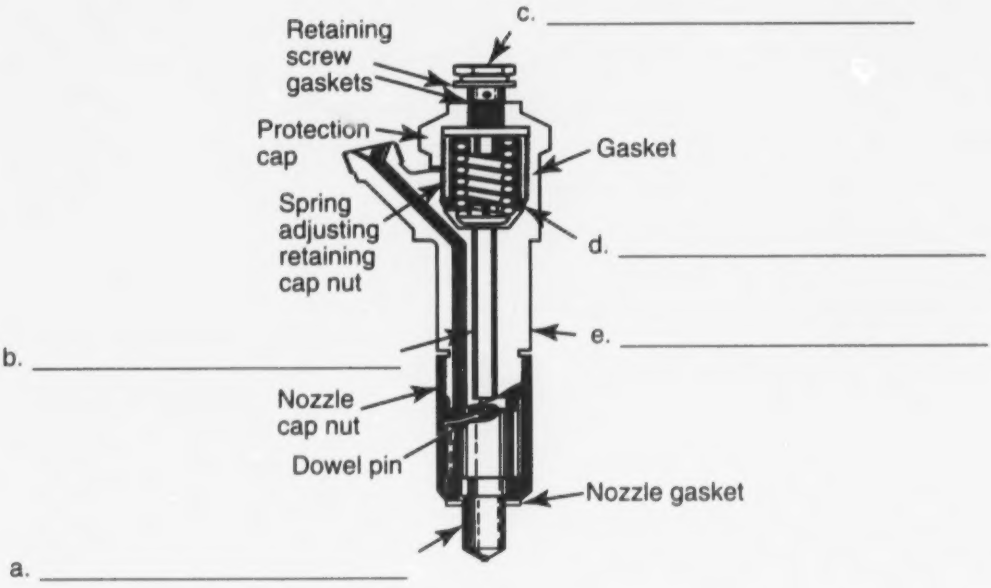
_____ m. Operated or moved by liquid in motion

_____ n. Oil passage that indexes with a port in a rotating head

Written Test

Objective 2

Label the parts of an injection nozzle. Write your answers in the blanks provided.


c. ______________________
Retaining screw gaskets
Protection cap
Gasket
Spring adjusting retaining cap nut
d. ______________________
e. ______________________
b. ______________________
Nozzle cap nut
Dowel pin
Nozzle gasket
a. ______________________

Objective 3

Distinguish between types of nozzle valves by placing an "M" next to the multiple orifice nozzle valve and an "S" next to the single hole pintle nozzle valve.

_____ a. Used on precombustion engines

_____ b. Used on direct injection engines

Objective 4

Complete statements concerning the operation of an injection nozzle by filling in the blanks with the correct answers.

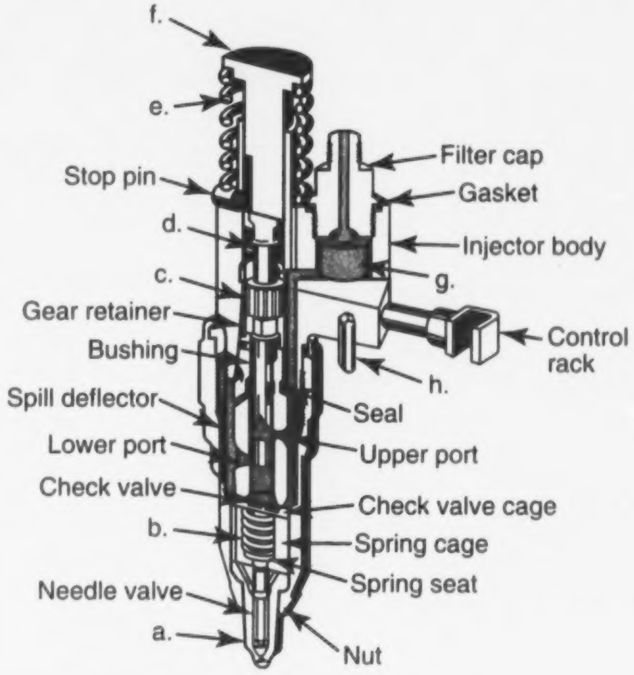
a. Fuel is delivered under pressure from the injection ______________________ to the injection ______________________ through passage to pressure chamber.

b. Spring-loaded valve is lifted allowing pressurized fuel to spray out through one or more ______________________ into combustion chamber.

c. Nozzle opening pressure is adjusted by a ______________________ on the valve spring.

Objective 5

Identify parts of mechanical unit injectors. Write your answers in the blanks provided.


f.
e.
Stop pin
d.
c.
Gear retainer
Bushing
Spill deflector
Lower port
Check valve
b.
Needle valve
a.
Filter cap
Gasket
Injector body
g.
Control rack
h.
Seal
Upper port
Check valve cage
Spring cage
Spring seat
Nut

Courtesy of Detroit Diesel Corporation

a.	______________________	e.	______________________
b.	______________________	f.	______________________
c.	______________________	g.	______________________
d.	______________________	h.	______________________

Objective 6

Arrange in order the steps describing the fuel flow through the unit injector by placing the correct sequence number (1–4) in the appropriate blank.

_____ a. Pump pressure forces fuel through small orifices in spray tip.

_____ b. Fuel enters injector through a filter cap and filter.

_____ c. Fuel is atomized into combustion chamber.

_____ d. Fuel passes through drilled passages and ports into supply chamber.

Written Test

Objective 7

List four optional features on fuel injection pumps.

a. ______________________________

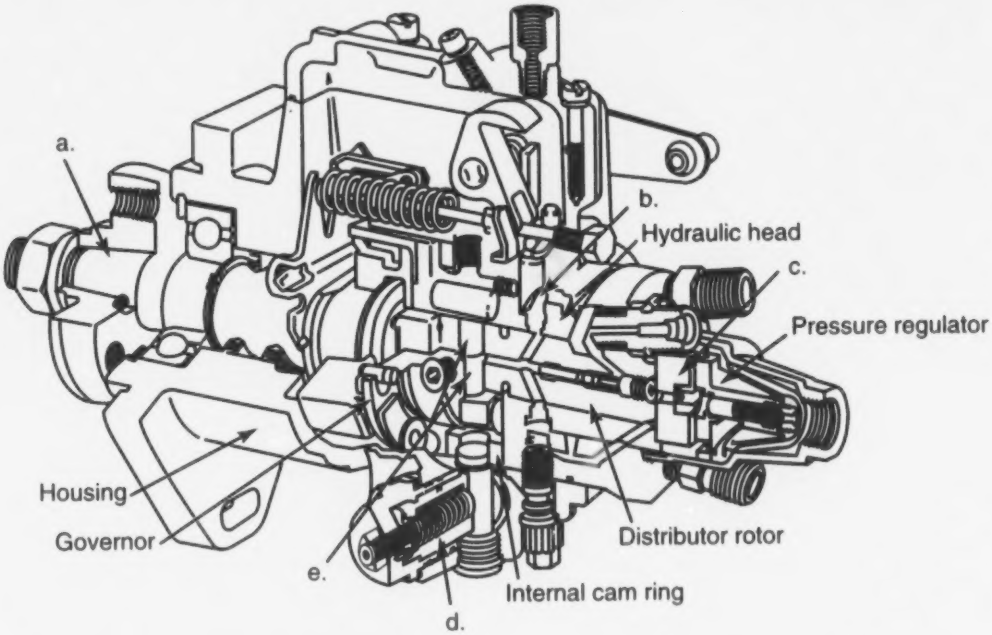
b. ______________________________

c. ______________________________

d. ______________________________

Objective 8

Identify the main parts of a distributor-type injection pump. Write your answers in the blanks provided.


a.
b.
Hydraulic head
c.
Pressure regulator
Housing
Governor
Distributor rotor
e.
Internal cam ring
d.

Courtesy of Stanadyne, Inc.

a. ______________________

b. ______________________

c. ______________________

d. ______________________

e. ______________________

Objective 9

Match the main parts of a distributor-type injection pump with the correct functions. Write the correct answers in the blanks provided.

1. Automatic advance
2. Distributor rotor
3. Drive shaft
4. Governor
5. Housing
6. Hydraulic head
7. Internal cam ring
8. Metering valve
9. Pressure regulator
10. Pumping plungers
11. Transfer pump

_____ a. Contains all component parts

_____ b. Provide pressure to transfer fuel from rotor to hydraulic head to injection nozzles

_____ c. Rotation of rotor causes pumping action of plungers which discharge fuel when passages index with appropriate passages in the hydraulic head

_____ d. Hydraulic servomechanism powered by fuel pressure from the transfer pump which advances injection timing

_____ e. Contains the metering valve and the bore in which the rotor revolves

_____ f. Actuates the pumping plungers

_____ g. Regulates the speed by positive mechanical linkage to metering valve

_____ h. Limits pressure of fuel to injection nozzles

_____ i. Regulates the quantity of fuel delivered to the cylinders

_____ j. Turns distributor rotor in the hydraulic head

Objective 10

Complete statements concerning the operation of distributor-type injection pumps by filling in the blanks with the correct answers.

a. Drive shaft engages the ____________________ in the hydraulic head.

b. ____________________ are actuated toward each other simultaneously by the internal cam-ring to pump fuel.

c. As rotor revolves inside hydraulic head, the discharge passage in the rotor indexes with appropriate passage in the hydraulic head to lead to the ____________________.

Written Test

Objective 11

Arrange in order the steps describing the fuel flow through distributor-type injection pumps by placing the correct sequence number (1-10) in the appropriate blank.

_____ a. The fuel flows around the annulus through a connecting passage to the metering valve.

_____ b. As the rotor revolves, the two inlet passages register with the charging ports in the hydraulic head, allowing fuel to flow into the pumping chamber.

_____ c. Fuel under transfer pump pressure flows past the rotor retainers into an annulus on the rotor.

_____ d. Fuel is drawn from the supply tank through filters into the pump through the inlet filter screen by the vane type fuel transfer pump.

_____ e. Fuel trapped between the plungers is then pressurized and delivered by the nozzle to the combustion chamber.

_____ f. Some fuel is by-passed through the pressure regulator assembly to the suction side.

_____ g. While the discharge port is opened, the rollers contact the cam lobes forcing the plungers together.

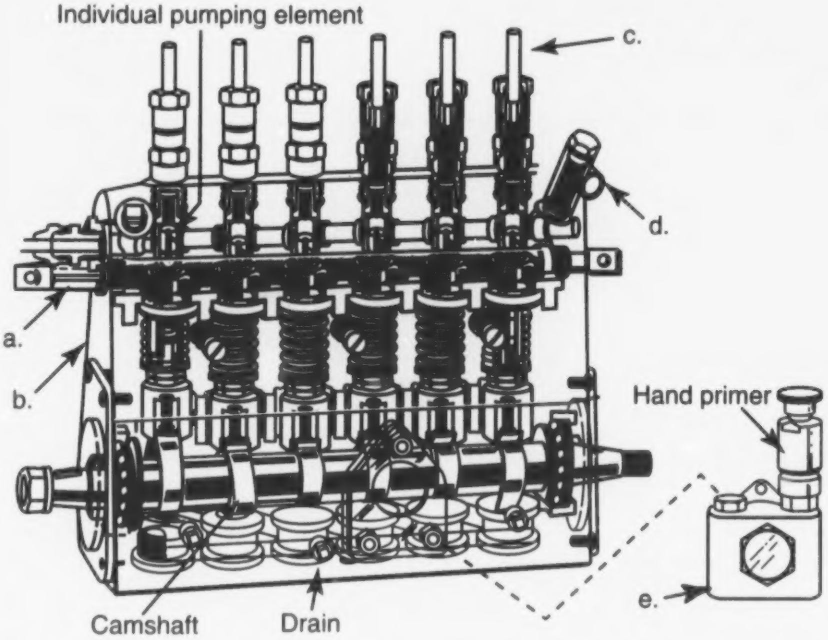
_____ h. Fuel then flows through a connecting passage in the head to the advance and also to the charging circuit.

_____ i. With further rotation, the inlet passages move out of registry and the discharge port of the rotor registers with one of the head outlets.

_____ j. The radial position of the metering valve, controlled by the governor, regulates the flow of fuel into the annulus which incorporates the charging ports.

Objective 12

Identify the main parts of an in-line injection pump. Write your answers in the blanks provided.


Individual pumping element
c.
d.
a.
b.
Hand primer
Camshaft
Drain
e.

Reprinted with permission of Ambac International Corporation

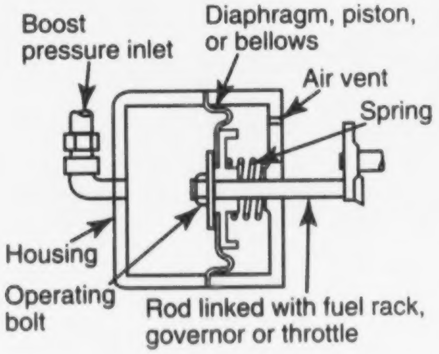
a. ______________________

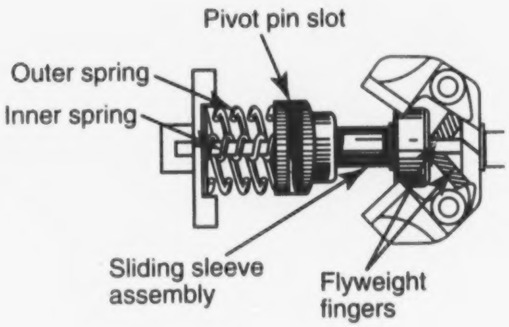
b. ______________________

c. ______________________

d. ______________________

e. ______________________


Boost pressure inlet
Diaphragm, piston, or bellows
Air vent
Spring
Housing
Operating bolt
Rod linked with fuel rack, governor or throttle


Pivot pin slot
Outer spring
Inner spring
Sliding sleeve assembly
Flyweight fingers

f. ______________________ g. ______________________

Reprinted with permission of Ambac International Corporation

Objective 13

Match the main parts of an in-line injection pump with their correct functions. Write the correct answer in the space provided.

1. Aneroid
2. Camshaft
3. Control rack
4. Fuel transfer pump
5. Governor
6. Hand primer
7. Individual pumping element
8. Injection line
9. Leak-off line
10. Pump housing
11. Sediment bowl

_____ a. Return line for excess fuel not used by injection nozzles

_____ b. Actuates the pumping plungers

_____ c. Pumps fuel when bleeding the system; commonly located on the fuel transfer pump

_____ d. Collects contaminants in the fuel system; commonly found on the bottom of filters

_____ e. Draws fuel from supply tank and then sends fuel at low pressure through filters to the injection pump

_____ f. Limits fuel supply to engine in order to prevent excess smoke

_____ g. Uses centrifugal force and spring tension to govern engine speed

_____ h. Opens or closes the helix on plunger to meter the quantity of fuel delivered to cylinders

_____ i. Rotates sleeve which connects to vanes on plunger

_____ j. Supply line for fuel to injection nozzles

Objective 14

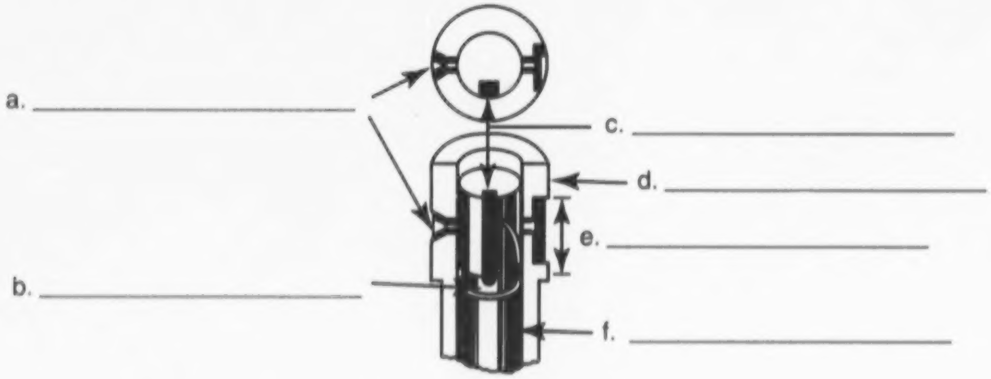
Complete statements concerning the operation of an in-line injection pump by circling the correct answers.

a. Plunger-type pump has engine-driven camshaft rotating at **(half-, full-)** engine speed.

b. Roller cam followers, riding on cam lobes, operate the plungers to supply **(low, high)** pressure fuel through delivery valves to injection nozzles.

Objective 15

Label the parts and design features of a pumping element.



Reprinted with permission of Ambac International Corporation

Objective 16

Complete statements concerning the operation of the control rack and sleeve by filling in the blanks with the correct answers.

a. Governor moves ____________________ to regulate speed of engine.

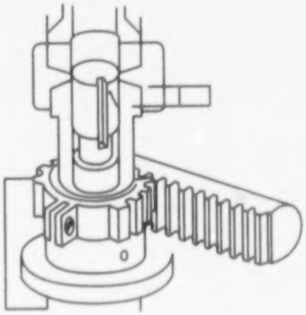
b. The sleeve, rotated by the control rack, is fitted over the barrel and connects to the ____________________ on the plunger.

c. Plunger rotation opens or closes the ____________________ which meters the quantity of fuel for delivery to cylinder.

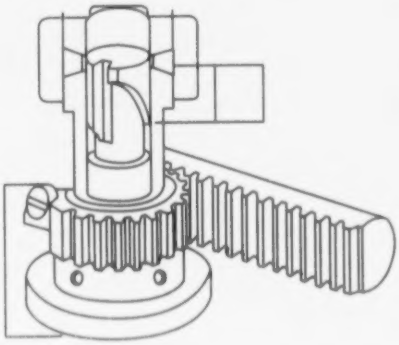
Written Test

Objective 17

Identify the plunger and rack positions. Write your answers in the blanks provided.



a. ______________________



b. ______________________

Objective 18

Select from the following list the types of PT injection pumps by placing an "X" in the appropriate blanks.

_____ a. PT type S—Solenoid regulated

_____ b. PTG-AFC—With air fuel ratio control

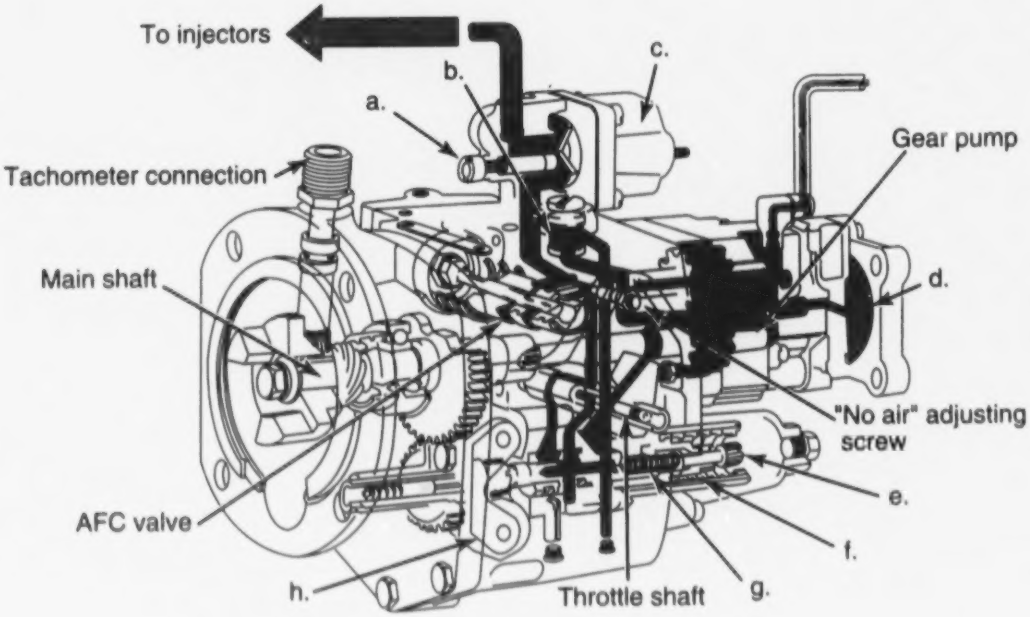
_____ c. PT type I—Injection controlled

_____ d. PT type G—Governor controlled

_____ e. EP—Electronic pump

Objective 19

Identify the main parts of a PT injection pump. Write your answers in the blanks provided.


To injectors
a.
b.
c.
Gear pump
Tachometer connection
Main shaft
d.
"No air" adjusting screw
e.
AFC valve
f.
h.
Throttle shaft
g.

Courtesy of Cummins Engine Company, Inc.

a. ____________________

b. ____________________

c. ____________________

d. ____________________

e. ____________________

f. ____________________

g. ____________________

h. ____________________

Written Test

Objective 20

Match the main parts of a PT injection pump with the correct functions. Write the correct answers in the blanks provided.

1. AFC valve
2. Gear pump
3. Governor assembly
4. Pulsation damper
5. Shut down valve
6. Throttle

_____ a. Provides manual control of fuel flow to injector under all conditions in operating range

_____ b. Absorbs pulsations and smoothes fuel flow through system

_____ c. Manifold pressure controls air-fuel ratio and fuel rate

_____ d. Draws fuel from supply tank forcing it through the pump filter screen

_____ e. Stops fuel flow for shut-down engine

_____ f. Controls flow of fuel from idle to maximum governor speed

Objective 21

Complete statements concerning the operation of a PT injection pump by filling in the blanks with the correct answers.

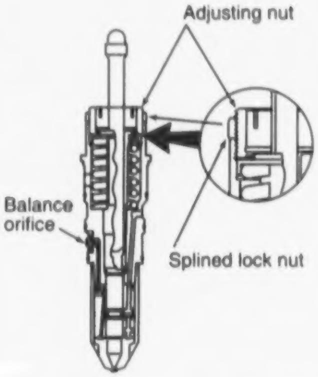
a. Gear type fuel pump delivers fuel through a restricting ______________________ to the governor.

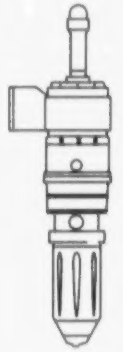
b. From the governor, the fuel goes to a ______________________ which feeds cam-operated injectors in the cylinder head.

c. Injector raises ______________________ to produce a good spray and times the start of injection.

Objective 22

Identify types of PT injectors. Write your answers in the blanks provided.





Courtesy of Cummins Engine Company, Inc.

a. ______________________ b. ______________________

Objective 23

Match the steps in the operation of PT injection with their correct descriptions. Write the correct answers in the spaces provided.

1. Cooling 2. Injection 3. Metering

_____ a. Downward plunger movement cuts off fuel entry into the injector cup and forces fuel through spray orifices into combustion chamber.

_____ b. Fuel enters the injector at fuel inlet, and balance orifice controls quantity of fuel that enters the injector cup.

_____ c. While plunger is down, fuel passes through upper hole around undercut in plunger through return passages to the fuel tank. Plunger remains seated.

*Permission to duplicate this test is granted.

Answers to Written Test

Objective 1

a. 3
b. 5
c. 10
d. 1
e. 6
f. 14
g. 7
h. 11
i. 4
j. 2
k. 15
l. 9
m. 8
n. 12

Objective 2

a. Nozzle assembly
b. Spindle assembly
c. Retaining screw
d. Pressure adjusting spring
e. Nozzle holder body

Objective 3

a. S
b. M

Objective 4

a. Pump, nozzle
b. Orifices
c. Screw or shims

Objective 5

a. Spray tip
b. Valve spring
c. Gear
d. Plunger
e. Follower spring
f. Follower
g. Filter
h. Dowel

Objective 6

a. 3
b. 1
c. 4
d. 2

Answers to Written Test

Objective 7

Any four of the following:

a. Altitude compensator
b. Aneroid control (smoke limiter)
c. Automatic load advance
d. Automatic speed advance
e. Centrifugal governor
f. Electric shut-off
g. Torque control
h. Viscosity compensator

Objective 8

a. Drive shaft
b. Metering valve
c. Transfer pump blades
d. Automatic advance
e. Pumping plungers

Objective 9

a.	5	f.	7
b.	10	g.	4
c.	2	h.	9
d.	1	i.	8
e.	6	j.	3

Objective 10

a. Distributor rotor
b. Plungers
c. Injector nozzles

Objective 11

a.	5	f.	2
b.	7	g.	9
c.	3	h.	4
d.	1	i.	8
e.	10	j.	6

Objective 12

a. Control rack
b. Pump housing
c. Injection line
d. Leak-off line
e. Fuel transfer pump
f. Aneroid
g. Governor

Objective 13

a.	9	f.	1
b.	2	g.	5
c.	6	h.	7
d.	11	i.	3
e.	4	j.	8

Objective 14

a. Half-
b. High

Objective 15	a. Spill ports b. Annular groove c. Vertical slot d. Barrel e. Helix f. Plunger
Objective 16	a. Rack b. Vanes c. Helix
Objective 17	a. Partial fuel delivery b. Maximum fuel delivery
Objective 18	b, d
Objective 19	a. Manual override b. Filter screw c. Shut down valve d. Pulsation damper e. Idle screw f. Governor spring g. Idle spring h. Governor weights
Objective 20	a. 6 b. 4 c. 1 d. 2 e. 5 f. 3
Objective 21	a. Throttle b. Manifold c. Pressure
Objective 22	a. Top stop b. STC
Objective 23	a. 2 b. 3 c. 1

Unit 2-C

Mechanical Fuel Injection Diagnosis and Repair

Prerequisites:
None

Learning Activities Sheet

Student Name ______________________________

Place a checkmark in the appropriate box as you complete each of the steps below.

☐ 1. **Take** Pretest provided by instructor. After test has been evaluated, follow instructor's recommendations.

☐ 2. **Read** Objective Sheet.

☐ 3. **Research** Online resources concerning injection systems pricing and availability. Visit www.ambac.net as one of your sources.

☐ 4. **View** Videotape entitled "Diesel Injection System Service".

☐ 5. **Study** Information Sheet, Objectives 1 through 4.

☐ 6. **Observe** Demonstration of procedures to be used in completing Job Sheet 1.

☐ 7. **Do** Job Sheet 1, "Isolate, Remove, Test, Rebuild or Replace, and Reinstall Injection Nozzles".

☐ 8. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 9. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 1 and repeat steps 6 through 8.

☐ 9. **Study** Information Sheet, Objectives 5 through 7.

☐ 10. **Observe** Demonstration of procedures to be used in completing Job Sheet 2.

☐ 11. **Do** Job Sheet 2, "Isolate, Remove, Test, and Reinstall or Replace Mechanical Unit Injectors".

☐ 12. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 13. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 2 and repeat steps 10 through 12.

☐ 13. **Study** Information Sheet, Objectives 8 through 11.

☐ 14. **Observe** Demonstration of procedures to be used in completing Job Sheet 3.

☐ 15. **Do** Job Sheet 3, "Inspect, Test, Adjust, and Time a Distributor-Type (Rotary) Injection Pump; Determine Needed Repairs".

☐ 16. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 17. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 3 and repeat steps 14 through 16.

☐ 17. **Study** Information Sheet, Objectives 12 through 17.

☐ 18. **Observe** Demonstration of procedures to be used in completing Job Sheet 4.

☐ 19. **Do** Job Sheet 4, "Inspect, Test, Adjust, and Time an In-Line Injection Pump; Determine Needed Repairs".

☐ 20. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 21. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 4 and repeat steps 18 through 20.

☐ 21. **Study** Information Sheet, Objectives 18 through 23.

☐ 22. **Observe** Demonstration of procedures to be used in completing Job Sheet 5.

☐ 23. **Do** Job Sheet 5, "Inspect, Test, and Adjust a PT Injection Pump and Time the Injectors; Determine Needed Repairs".

☐ 24. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 25. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 5 and repeat steps 22 through 24.

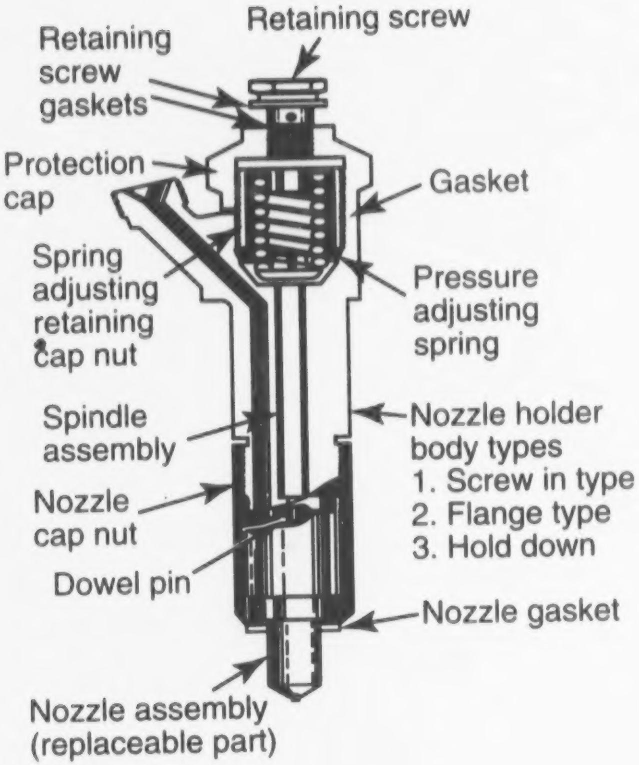
☐ 25. **Check** With instructor for any additional assignments to be completed.

☐ 26. **Take** Posttest provided by instructor. After test has been evaluated, follow instructor's recommendations.

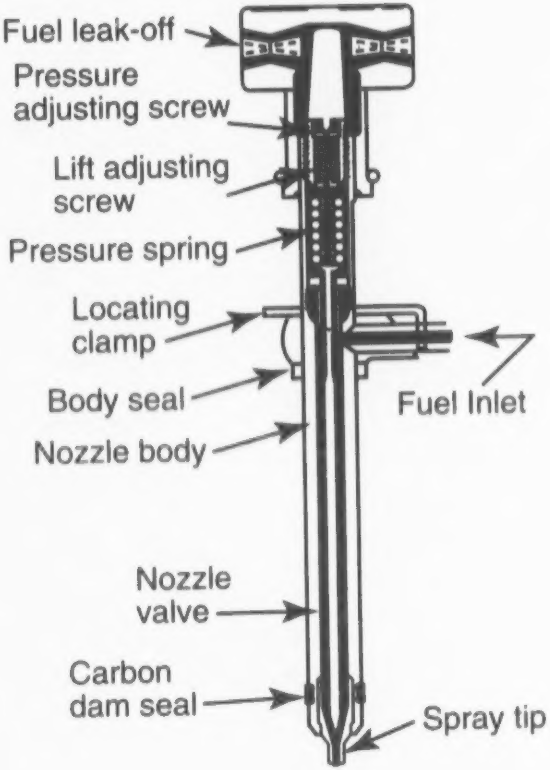
☐ 27. **Stop** Have instructor evaluate your unit performance. If the evaluation is satisfactory, proceed to next learning activities sheet. If evaluation is not satisfactory, ask instructor for further instructions.

***Permission to duplicate this form is granted.**

Parts of Injection Nozzles

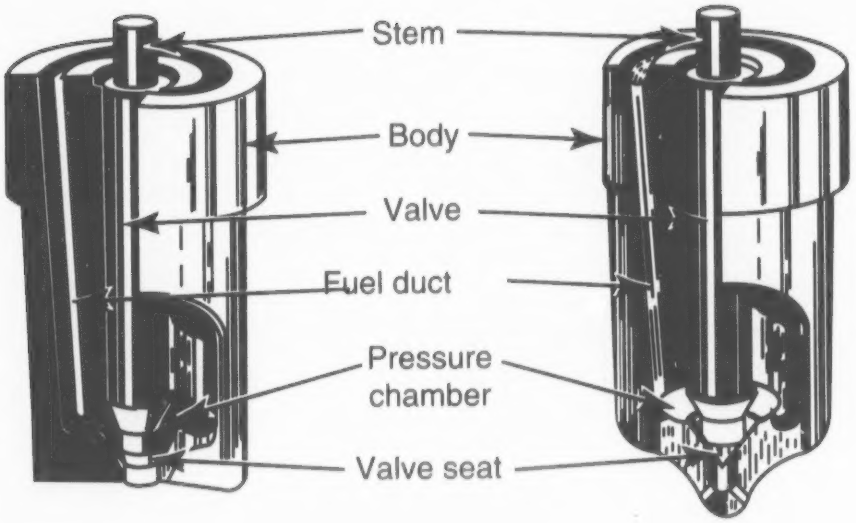

Retaining screw
Retaining screw gaskets
Protection cap
Gasket
Spring adjusting retaining cap nut
Pressure adjusting spring
Spindle assembly
Nozzle holder body types
1. Screw in type
2. Flange type
3. Hold down
Nozzle cap nut
Dowel pin
Nozzle gasket
Nozzle assembly (replaceable part)

Typical


Fuel leak-off
Pressure adjusting screw
Lift adjusting screw
Pressure spring
Locating clamp
Fuel Inlet
Body seal
Nozzle body
Nozzle valve
Carbon dam seal
Spray tip

Pencil-Type

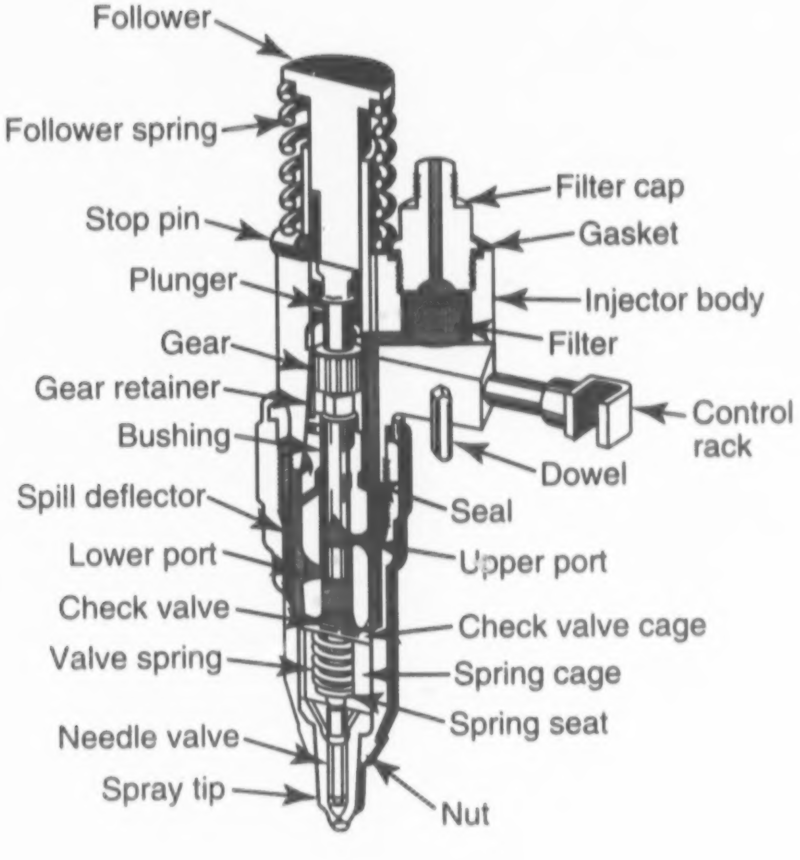
Types of Nozzle Valves


Stem
Body
Valve
Fuel duct
Pressure chamber
Valve seat

Single Hole Pintle

Multiple Orifice

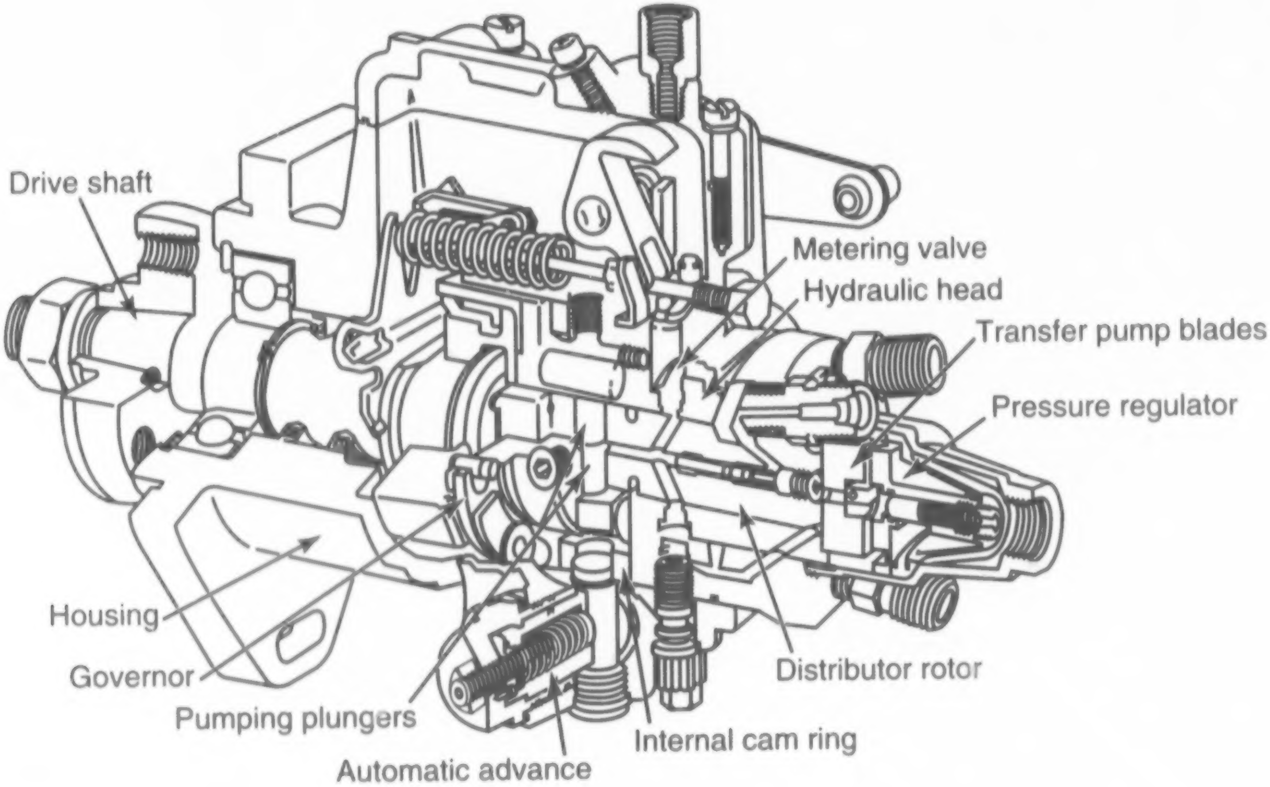
Parts of a Mechanical Unit Injector


Follower
Follower spring
Stop pin
Plunger
Gear
Gear retainer
Bushing
Spill deflector
Lower port
Check valve
Valve spring
Needle valve
Spray tip
Filter cap
Gasket
Injector body
Filter
Control rack
Dowel
Seal
Upper port
Check valve cage
Spring cage
Spring seat
Nut

Courtesy of Detroit Diesel Corporation

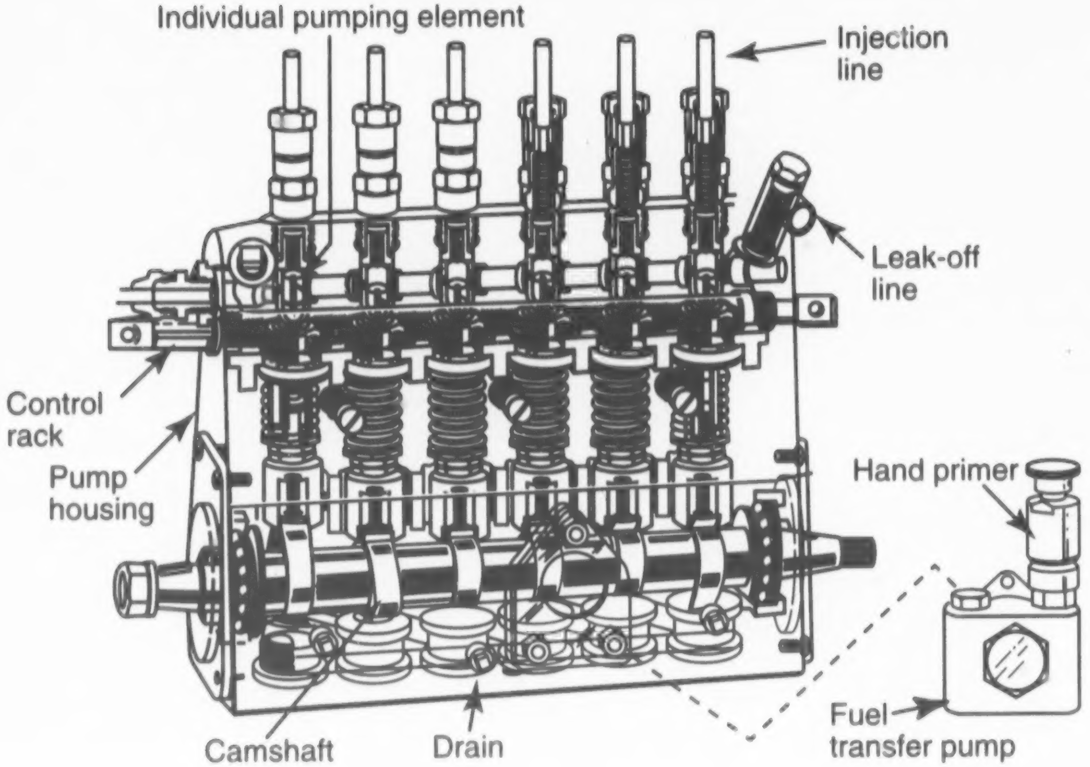
TM 3

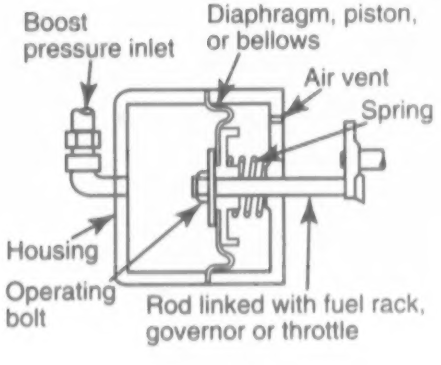
Parts of a Distributor-Type Injection Pump


Drive shaft
Metering valve
Hydraulic head
Transfer pump blades
Pressure regulator
Housing
Governor
Pumping plungers
Automatic advance
Internal cam ring
Distributor rotor

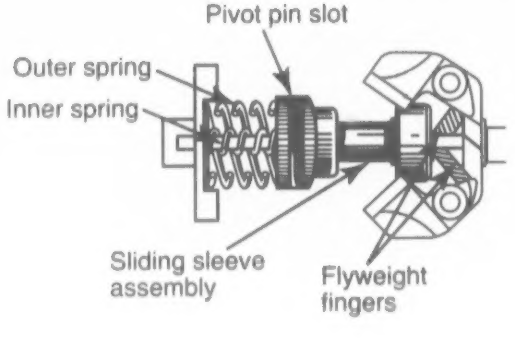
Courtesy of Stanadyne, Inc.

Main Parts of an In-Line Injection Pump


Individual pumping element
Injection line
Leak-off line
Control rack
Pump housing
Hand primer
Camshaft
Drain
Fuel transfer pump


Boost pressure inlet
Diaphragm, piston, or bellows
Air vent
Spring
Housing
Operating bolt
Rod linked with fuel rack, governor or throttle

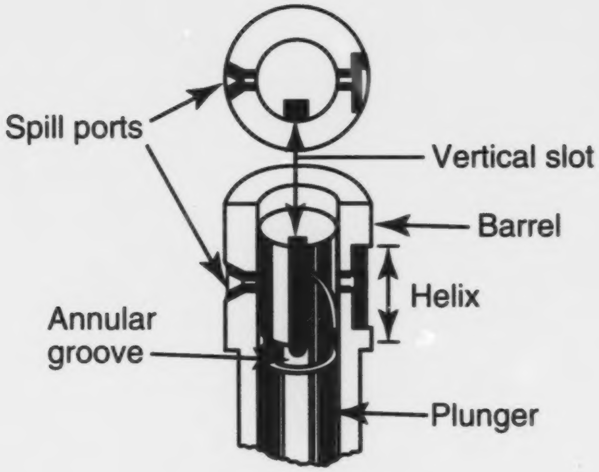
Aneroid


Pivot pin slot
Outer spring
Inner spring
Sliding sleeve assembly
Flyweight fingers

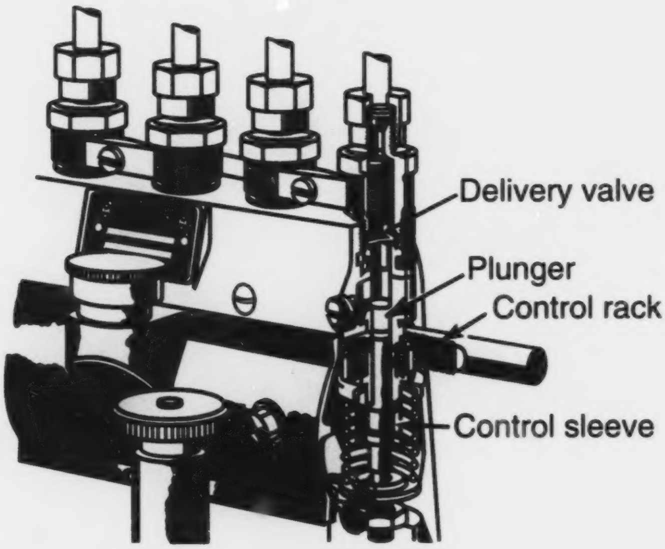
Governor

Reprinted with permission of Ambac International Corporation

Pump Details


Spill ports
Vertical slot
Barrel
Helix
Annular groove
Plunger

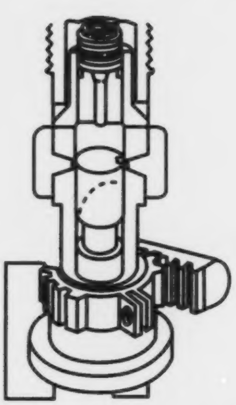
Pumping Element


Delivery valve
Plunger
Control rack
Control sleeve

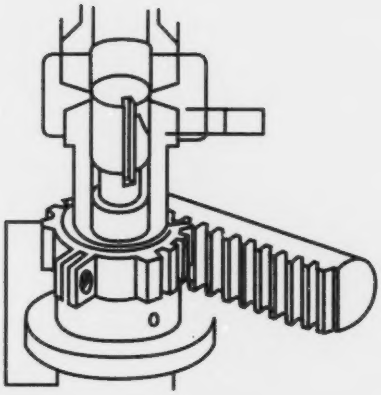
Control Rack and Sleeve

Reprinted with permission of Ambac International Corporation

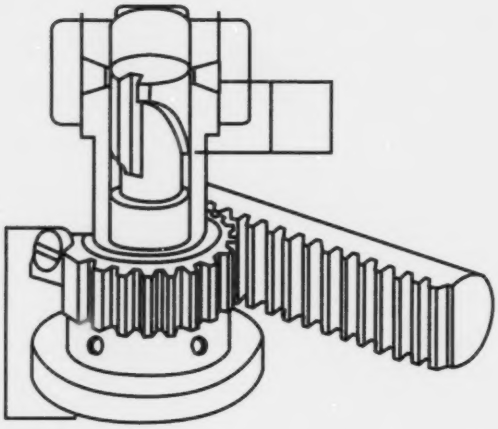
Plunger and Rack Positions



No fuel delivery

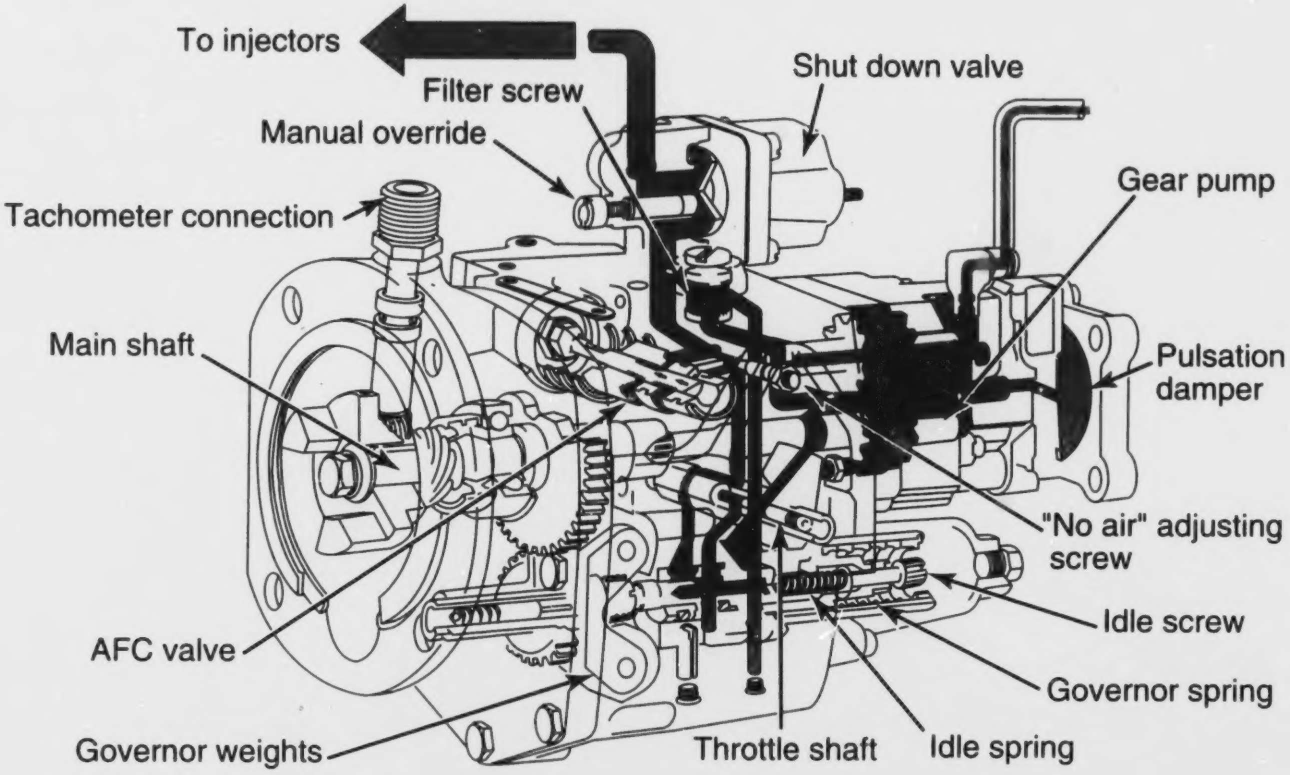


Partial fuel delivery



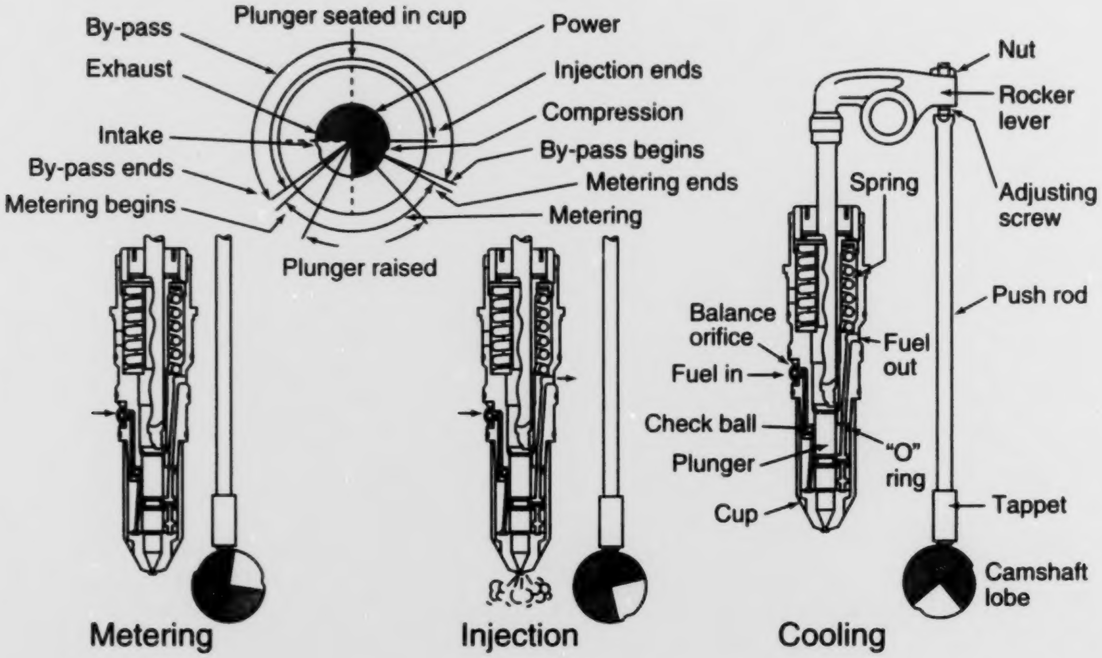
Maximum fuel delivery

Main Parts of a PT Injection Pump


To injectors
Filter screw
Shut down valve
Manual override
Tachometer connection
Gear pump
Main shaft
Pulsation damper
"No air" adjusting screw
Idle screw
AFC valve
Governor spring
Governor weights
Throttle shaft
Idle spring

Courtesy of Cummins Engine Company, Inc.

Operation of PT Injectors


By-pass
Plunger seated in cup
Power
Exhaust
Injection ends
Compression
Intake
By-pass begins
By-pass ends
Metering ends
Metering begins
Metering
Plunger raised
Nut
Rocker lever
Spring
Adjusting screw
Push rod
Balance orifice
Fuel in
Fuel out
Check ball
Plunger
"O" ring
Cup
Tappet
Camshaft lobe
Metering
Injection
Cooling

Courtesy of Cummins Engine Company, Inc.

Unit 3-C

Electronic Fuel Injection Diagnosis and Repair

Unit Contents

Teacher Components

Teacher Page

Suggested Activities 3C–3

Written Test 3C–9

Answers to Written Test 3C–19

Learning Activities Sheet 3C–23

Transparency Masters

1—Parts of a Typical Electronic Fuel System 3C–27
2—Parts of an Electronic Unit Injector 3C–29
3—Common Types of Electronic Fuel Injection Systems 3C–31
4—Common Types of Electronic Fuel Injection Systems (Continued) 3C–33
5—Common Types of Electronic Fuel Injection Systems (Continued) 3C–35
6—Basic Categories of Electronic Components 3C–37

Student Components

Student Page

Objective Sheet 3C–3

Information Sheet 3C–5

Student Supplement

1—SAE Fault Codes 3C–17

Job Sheets

1—Inspect and Test Power and Ground Circuits and Connections; Determine Needed Repairs 3C–19
2—Check Diagnostic Trouble Codes Using Scan Tools and Technical Information; Determine Needed Repairs 3C–23
3—Inspect and Replace Electrical Connectors, Terminals, Seals, and Locks 3C–27
4—Access Engine Parameters; Monitor or Change as Requested by Customer 3C–31
5—Remove, Inspect, and Rebuild or Replace a Fuel Transfer Pump 3C–35
6—Remove, Inspect, Reinstall, and Adjust Electronic Unit Injectors; Determine Needed Repairs 3C–39

Suggested Activities

Instructional Plan

Preparation

- Read the unit carefully and plan for instruction.
- Review "Teaching Suggestions." Plan for classroom activities.
- Plan your presentation to take advantage of student learning styles and to accommodate special-needs students.
- Prepare classroom. Put up posters and charts and display articles and other references related to this unit.
- Obtain films, videotapes, and other resources to supplement instruction of this unit. See "Resources Used in Developing This Unit" and "Suggested Supplemental Resources" for more information.
- For self-paced instruction, review Learning Activities Sheet. Modify as appropriate to include additional activities and/or resources available in your classroom. Make one copy for each student.
- Make copies of any teacher supplements that will be provided for each student.
- Make transparencies from the transparency masters included in this unit. These appear in the teacher edition only.

Delivery and Application

Unit Introduction (self-paced instruction)

- Provide student with Learning Activities Sheet and unit of instruction.
- Review unit contents with student.
- Have the student complete the steps in the learning activities sheet.

Unit Introduction (group instruction)

- Provide students with unit of instruction.
- Discuss unit and specific objectives.
- Discuss the information sheet. Implement teaching plan to localize, supplement, and personalize the unit. Reinforce basic academic and workplace skills when applicable.

Suggested Activities

- Discuss and demonstrate the job sheets. Make sure all required tools, equipment, and materials are available. Review with students the criteria for evaluation of these activities and the rating scale that will be used to indicate job performance.

Teaching Suggestions

- Discuss the safety hazards associated with working on electronic engines. Personalize the information by relating any experiences you have had with accidents or mishaps that occurred when working around electronics.

- Provide examples of assembled diesel engine equipment/vehicles so students can identify the parts of the electronic fuel system. Provide students with heavyweight paper cards already labeled with the part names and have students tape the correct cards to the correct parts. This should help students see the "big picture."

- Show students individual examples of basic electronic fuel system components including:

  — Electronically controlled module (ECM)

  — Electronically controlled unit injectors

  — Electronic governors

  — Electronic sensors

  — Fuel pumps

  — Pressure regulator and bypass or check valves

  Discuss their designs and operation. Allow students to handle the parts and become familiar with them.

- Construct a mock-up of an electronic fuel system, and discuss with students the basic components, operation, and fuel flow through the system. Also help students classify the components as input, control, or output.

- Discuss the many advantages of electronic fuel injection over mechanical fuel injection as outlined in Objective 5. Also have students brainstorm to identify some of the disadvantages of electronic systems.

- Discuss the most common problems that you have encountered with electronic fuel systems. Also discuss how these problems affected the engine. Describe the inexpensive precautions (new seals, fresh lubricant, new filters, etc.) that could have saved the owner from expensive engine wear/failure problems. Stress the economic benefits of preventive maintenance.

- Show examples of the different types of electronic fuel injection systems as outlined in Objective 6, and then have students identify the systems shown.

- Discuss the characteristics of the different types of electronic fuel injection systems, including their advantages and disadvantages.

- Make a display of all specialty electronic diagnosis tools covered in Objective 10 with identifying labels so students can practice identifying them. You may wish to then remove the labels and give students a hands-on practical test to identify the tools on display. This test/quiz may be conducted individually or as a class group or team activity.

- Discuss the different manufacturers' methods of storing and retrieving computer fault information. Show the different parts and equipment involved and how they are similar and how they are different.

- Obtain from manufacturers up-to-date service manuals, bulletins, troubleshooting guides, videos, and brochures that explain electronic engine diagnosis. Provide for students so they can appreciate current technology.

- Demonstrate how to connect electronic diagnostic equipment. Also discuss how manufacturers may have slight modifications for their equipment.

Evaluation

- Make copies of the written test. Add or modify test items as needed. The written test serves as both a pretest and posttest to assist in measuring each student's competency gains.

- Give and evaluate pretest. Modify lesson plan to include additional instruction for those areas where students were deficient.

- Evaluate the job sheets. When the student is ready to perform a specific task, obtain a copy of the job sheet which may be found in the student edition. Then observe the student performing the procedure.

Suggested Activities

Process evaluation—Place a mark in the box to the left of each designated checkpoint if the student has satisfactorily completed the process step(s) for each checkpoint area. If the student is unable to complete the procedure correctly, have the student review the materials and try again.

Product evaluation—Once the student has satisfactorily completed the procedure, rate the student product (outcome) using the criteria that are provided as part of the job sheet. If the student's product is unacceptable, have the student review the materials and submit another product for evaluation.

Two sample performance evaluation keys have been provided below. Many other keys are available. Select one rating (grading scale) that best fits your program needs.

Sample A

4—**Skilled**—Can perform job with no additional training.
3—**Moderately skilled**—Has performed job during training program; limited additional training may be required.
2—**Limited skill**—Has performed job during training program; additional training is required to develop skill.
1—**Unskilled**—Is familiar with process, but is unable to perform job.
0—**No exposure**—No information or practice provided during training program.

Sample B

Yes—Can perform job with no additional training.
No—Is unable to perform job satisfactorily.

- Give and evaluate the posttest.
- Meet individually with students to evaluate their progress through this unit of instruction and indicate to them possible areas of improvement.
- Reteach and retest as required.

Resources Used in Developing This Unit

Print Media

- Clark, Elton, et al. *Diesel Fundamentals*. Stillwater, OK: Mid-America Vocational Curriculum Consortium, Inc., 1988.
- Dagel, John F. *Diesel Engine and Fuel System Repair*, 3rd ed. Upper Saddle River, NJ: Prentice Hall, 1994.
- Espenschied, Roland F. *Diesel Engines*. Athens, GA: American Association for Vocational Instructional Materials, 1990.

Suggested Supplemental Resources

Print Media

- *ASE Test Prep Series*—Medium/Heavy Duty Truck, 2nd ed. (Diesel Engines). Albany, NY: Delmar Publishers, 2002.

  Also available in CD ROM format
- Bennett, Sean. *Medium/Heavy Duty Truck Engines, Fuel and Computerized Management Systems.* Albany, NY: Delmar Publishers, 1999.
- Bennett, Sean. *Today's Technician: Medium/Heavy Duty Truck Diesel Engines.* Albany, NY: Delmar Publishers, 2001.
- Brady, Robert. *Diesel Engine and Fuel System Repair*, 5th ed. Upper Saddle River, NJ: Prentice Hall inc., 2002.
- *DDEC II Troubleshooting Guide* (06SE 0489)
- *DDEC III Troubleshooting Guide* (06SE 049)
- *DDEC II Diagnostic Code Card*, 50/pkg (07SE 0410)
- *DDEC III Code Card*, (07SE 0414)

  The above are available from your local Detroit Diesel distributor/dealer or order from the following company. Also check for new guides and cards, as well as new videotapes, as new electronic control systems become available.

  Robot Literature Distribution

  12085 Dixie

  Redford, MI 48239

  Phone: 313-255-9300 or Fax: 313-255-7680
- *Medium Duty Truck Electronic Fuel Injection (EFI) Training Course* (96090.00). Two-day course that covers the operation and service procedures for the throttle body fuel injection unit, exhaust emission components, fuel system diagnostics and scan tool usage. Contact your local GM/GMC Truck dealer for more information about course dates and locations. A GM Training Materials catalog is available from:

  General Motors Training Materials
  Mascotech Mktg. Service
  1972 Brown Road
  Auburn Hills, MI 48326
  800-393-4831

- *Deutsch Connectors Service Manual.* (8.6) Available from:

  Mack Trucks, Inc.
  2100 Mack Boulevard
  P.O. Box M
  Allentown, PA 18195-5000
  610-439-3011

Electronic Media

- *Fuel System*, VHS, 37 minutes

  Provides instruction for the maintenance of a diesel engine fuel system. Includes: fuel line, changing the filter, bleeding the fuel valves, disassembly of an injector nozzle and testing.

- *Diesel Injection System Service*, VHS, 27 minutes

  Uses live action footage and computer animation to explain various types of diesel injection systems.

  NIMCO
  P.O. Box 9
  102 Hwy. 81 N.
  Calhoun, KY 42327-0009
  1-800-962-6662
  www.nimcoinc.com

- *3500 Electronic Engine Controls–Introduction* (SEGV2588), 32 slides. (1993)
- *EUI Service Introduction* (SEVN2241), 27-minute video. (1993)
- *Proper Governor Adjustment Using the 6V4060 Engine Set Point Indicator* (SEVN9174), 21-minute video.)1984)
- *Using the 6V4002 Unit Injector Tester* (SEVN9169), 17-minute video. (1983)

  The 4 titles listed above are available from your local CAT dealer or write the following for more information:

  Caterpillar Service Training
  600 W. Washington St., Bldg. JJ
  East Peoria, IL 61630

- *How to Troubleshoot Electrical Shorts and Grounds* (84-1) videotape (VHS)—GMC Truck. Available from:

  Regan Productions, Inc.
  Service Film Library
  19730 Ralston
  Detroit, MI 48203
  313-368-3000

Written Test

Name ____

Date ______________________________ Score__________

Objective 1

Match terms related to electronic fuel injection. with their definitions. Definitions continue on the next page. Write the correct answers in the blanks provided.

1. Active codes
2. Actuator
3. Bypass circuit
4. Calibration
5. Computer data link
6. Data
7. Diagnostic code
8. Driver
9. Electronic control module (ECM)
10. Harness
11. Historical or inactive codes
12. Microprocessor
13. On-demand test
14. Parameter
15. Personality module
16. Potentiometer
17. Pulse width
18. Random access memory (RAM)
19. Read only memory (ROM)
20. Reference voltage
21. Sensor
22. Signal
23. Solenoid
24. Thermistor
25. Threshold value
26. Transducer

_____ a. Sensor used to determine temperature

_____ b. Circuit, usually temporary, used to substitute for an existing circuit, typically for test purposes

_____ c. Length of time an actuator, such as an injector, remains energized

_____ d. Electronic device that controls the amount of fuel delivered by the injector

_____ e. Connection between two electronic devices for communication purposes; used for programming and troubleshooting

_____ f. Device used to detect and convert a change in a measurement (such as pressure, temperature, or movement) into an electrical signal

_____ g. Codes describing condition that is currently present to alert driver or service technician of abnormal parameters

_____ h. Device that converts a mechanical signal to an electrical signal; used to sense pressure

Written Test

_____ i. Type of memory used to store information permanently; cannot be written over

_____ j. Adjustment of a sensor signal

_____ k. Regulated voltage supplied by the electronic control module to a sensor; used by sensor to generate a signal voltage

_____ l. Digital readout that identifies a problem or event in an electronic system

_____ m. Wiring bundle connecting all electronic components

_____ n. Electro-mechanical device that senses the position of a mechanical component

_____ o. Integrated circuit within a microcomputer that controls information flow within the computer

_____ p. Information in numerical form that can be digitally transmitted or processed

_____ q. Value stored in the ROM portion of the ECM which is used for comparison to a sensor's value

_____ r. Voltage or waveform used to transmit information, usually from a sensor to the electronic control module

_____ s. Computerized device that monitors other electronic parts and acts as a governor in electronic fuel systems

_____ t. Transistor in the output section of the ECM used to turn on or off various actuators in the system

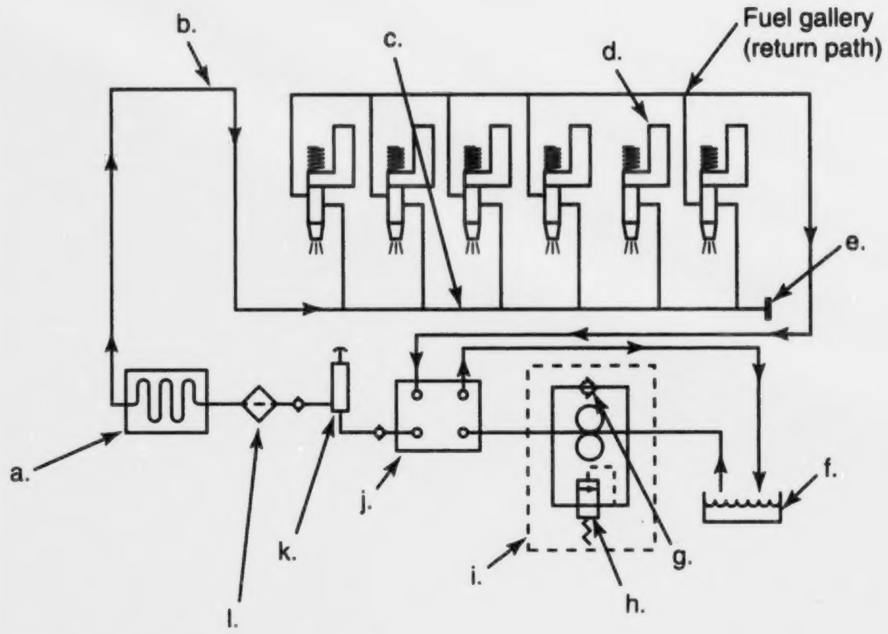
_____ u. Programmable value that affects the characteristics or behavior of the engine and/or vehicle

_____ v. Type of memory used to store information; can be written to and read from

Written Test

Objective 2

Identify the parts of a typical electronic fuel system. Write your answers in the blanks provided.


b.
c.
d.
Fuel gallery (return path)
e.
a.
f.
j.
k.
i.
g.
h.
l.

Courtesy of Caterpillar, Inc.

a. ______________________________

b. ______________________________

c. ______________________________

d. ______________________________

e. ______________________________

f. ______________________________

g. ______________________________

h. ______________________________

i. ______________________________

j. ______________________________

k. ______________________________

l. ______________________________

Written Test

Objective 3

Arrange in order the steps describing the fuel flow through an electronic fuel system by placing the correct sequence number (1-9) in the appropriate blanks.

_____ a. ECM senses timing and sends signal to injector solenoid to energize it.

_____ b. ECM deenergizes solenoid which shuts off fuel.

_____ c. Fuel then goes through possible distribution block, priming pump, secondary fuel filter, cooler plate on ECM, and to the cylinder head inlet passage.

_____ d. Energized solenoid opens fuel flow through injector body which is pushed by plunger operated by cam lobe on engine.

_____ e. Fuel is sent to injectors.

_____ f. Cam lobe rotates allowing plunger to lift, ready for next stroke.

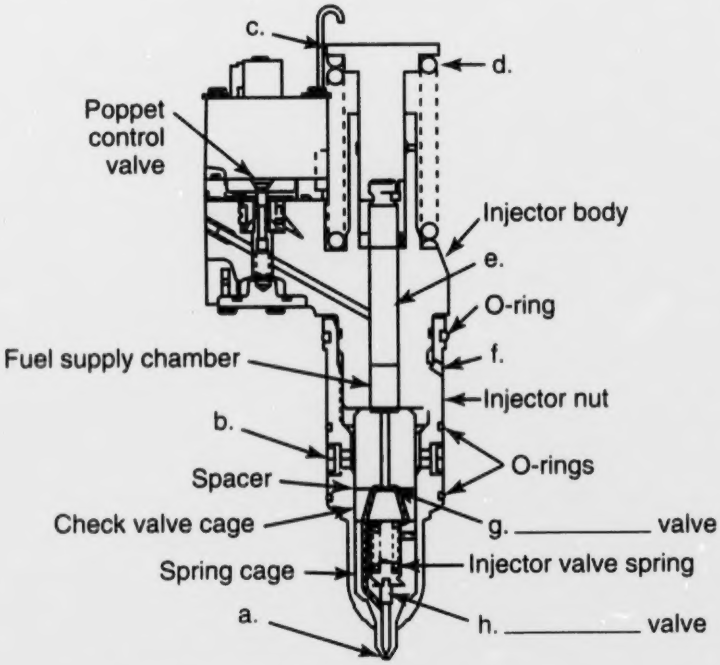
_____ g. Fuel is drawn from tank through a possible primary fuel filter (or strainer) and enters the fuel transfer pump.

_____ h. Fuel is pushed down to injection nozzle and then is sprayed into combustion chamber under very high pressure.

_____ i. Return fuel from injector is routed back to fuel tank.

Objective 4

Identify the parts of an electronic unit injector. Write your answers in the blanks provided.


c.
d.
Poppet control valve
Injector body
e.
O-ring
Fuel supply chamber
f.
Injector nut
b.
O-rings
Spacer
Check valve cage
g. ________ valve
Spring cage
Injector valve spring
a.
h. ________ valve

Courtesy of Detroit Diesel Corporation

a. ______________________________

b. ______________________________

c. ______________________________

d. ______________________________

e. ______________________________

f. ______________________________

g. ______________________________

h. ______________________________

Written Test

Objective 5

Describe five advantages of electronic fuel injection over mechanical fuel injection.

a. ______________________________

b. ______________________________

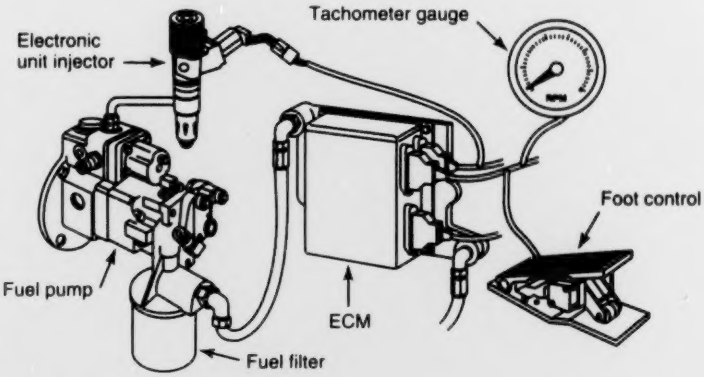
c. ______________________________

d. ______________________________

e. ______________________________

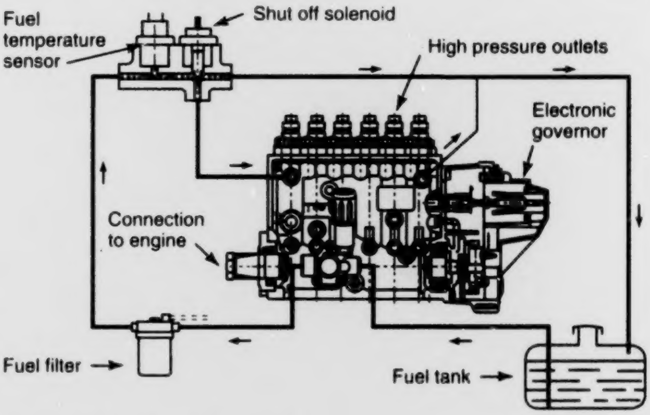
Objective 6

Identify common types of electronic fuel injection systems. Write your answers in the blanks provided. Illustrations continue on the next page.


Electronic unit injector
Tachometer gauge
Foot control
Fuel pump
ECM
Fuel filter

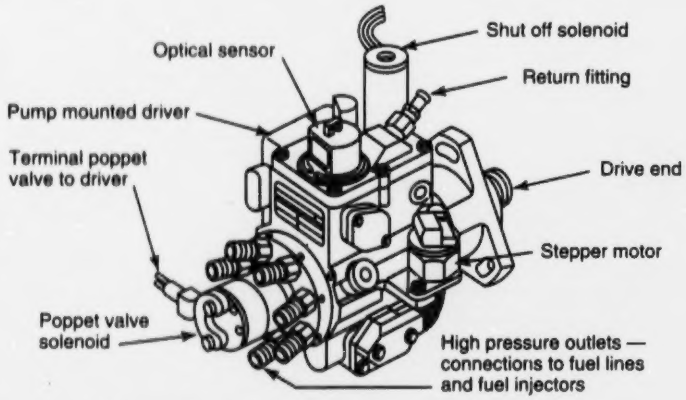
Courtesy of Cummins Engine Company, Inc.

a. ______________________________


Fuel temperature sensor
Shut off solenoid
High pressure outlets
Electronic governor
Connection to engine
Fuel filter
Fuel tank

Courtesy of Robert Bosch Corporation

b. ______________________________


Shut off solenoid
Optical sensor
Return fitting
Pump mounted driver
Terminal poppet valve to driver
Drive end
Stepper motor
Poppet valve solenoid
High pressure outlets — connections to fuel lines and fuel injectors

Courtesy of General Motors Corporation

c. ______________________________

Objective 7

Distinguish between the basic categories of electronic components by placing an "I" next to input components, "C" next to control components, and an "O" next to output components.

_____ a. Contains the microcomputer, voltage reference regulator, input conditioners, and output drivers

_____ b. Includes sensors and switches

_____ c. Receives electrical energy signals from ECM

_____ d. Includes electronic components (actuators) that perform work, such as solenoids, and electrical warning devices (lights and alarms)

_____ e. Receives input signals and sends output signals

_____ f. Sends electrical signals (high speed or low speed) to the ECM

Objective 8

List six common electronic sensors.

a. ______________________________

b. ______________________________

c. ______________________________

d. ______________________________

e. ______________________________

f. ______________________________

Written Test

Objective 9

Describe the meanings of the following common electronic acronyms and abbreviations.

a. CEL— ______________________________

b. DDL— ______________________________

c. ECAP— ______________________________

d. ECM— ______________________________

e. EDU— ______________________________

f. EUI ______________________________

g. ICM ______________________________

h. PROM ______________________________

Objective 10

Match specialty tools and equipment used for electronic diagnosis with their correct descriptions. Definitions continue on the next page. Write the correct answers in the blanks provided.

1. Adapter cables, breakout T cables, and probes
2. Brass brush for electronic injection nozzle tips
3. Diagnostic jumper wires
4. Digital multimeter (or DVOM)
5. Electronic service (scan) tool
6. Injector tube installation/removal tools
7. Oscilloscope
8. Personal computer (PC) with diagnostic software
9. PROM removal tool
10. Terminal crimping tool
11. Terminal removal tool
12. Testing harness

_____ a. Used to read diagnostic codes, change parameters, and obtain engine monitoring information

_____ b. Used for removing defective memory chips or upgrading memory chips

_____ c. Used with service tools in order to access measurements of signals

_____ d. Used for replacing ends on wiring harnesses

_____ e. Used to replace defective injector tubes

_____ f. Used for checking voltages and resistance

_____ g. Hand-held scanning device used to access diagnostic and programming information in order to locate problems in the electronic system

_____ h. For cleaning nozzle tips

_____ i. Used for jumping terminals when troubleshooting

_____ j. Typically inserted between two ends of a connector to permit normal circuit operation while measuring voltages

Objective 11

List four basic types of diagnostic codes.

a. ______________________________

b. ______________________________

c. ______________________________

d. ______________________________

Objective 12

Distinguish between standardized SAE and non-standardized electronic message identification codes by placing an "S" next to the standardized codes and an "NS" next to those that are non-standardized.

_____ a. FMI

_____ b. PID

_____ c. Flash codes

_____ d. SID

***Permission to duplicate this test is granted.**

Answers to Written Test

Objective 1

a. 24
b. 3
c. 17
d. 23
e. 5
f. 21
g. 1
h. 26
i. 19
j. 4
k. 20
l. 7
m. 10
n. 16
o. 12
p. 6
q. 25
r. 22
s. 9
t. 8
u. 14
v. 18

Objective 2

a. Electronically controlled module (ECM)
b. Fuel supply line
c. Fuel gallery (supply path)
d. Electronically controlled unit injectors
e. Drain plug
f. Fuel tank
g. Check valve
h. Pressurized regulating valve
i. Fuel transfer pump
j. Distribution block
k. Fuel priming pump
l. Fuel filter

Objective 3

a. 4
b. 7
c. 2
d. 5
e. 3
f. 8
g. 1
h. 6
i. 9

Objective 4

a. Spray tip
b. Fuel inlet opening
c. Injector follower
d. Injector follower spring
e. Plunger
f. Fuel outlet opening
g. Check valve
h. Needle valve

Answers to Written Test

Objective 5

Answers should include five of the following in student's own words:

a. Improved engine governing, timing, and fuel/air ratios
b. Improved engine performance
c. Reduced fuel consumption
d. Reduced emission levels
e. Enhanced cold starting
f. Improved diagnosis of engine malfunctions resulting in:
  - Reduced troubleshooting (down) time
  - Reduced labor costs
g. Increased flexibility
  - Parameters can be changed electronically, instead of manually.
  - Parameters can be changed so vehicle can operate at different loads, altitudes, and terrains.
h. Improved engine protection
  - Engine can be programmed to shutdown before dangerous limits are reached.
  - System is more tamper resistant with multilevel security.
  - Engine warm-up can be programmed.

Objective 6

a. Electronic unit injectors
b. In-line injection pump with electronic governor
c. Distributor-type injection pump with electronic governor

Objective 7

a. C
b. I
c. O
d. O
e. C
f. I

Objective 8

Any six of the following:

a. Automatic pressure sensor
b. Boost pressure sensor (inlet manifold air pressure)
c. Coolant level sensor
d. Coolant temperature sensor
e. Engine speed/timing sensor
f. Fuel temperature sensor
g. Intake manifold air temperature sensor
h. Oil pressure sensor
i. Oil temperature
j. Synchronous reference
k. Throttle position sensor
l. Timing reference
m. Vehicle speed sensor (rotation of gear teeth in drive train)

Answers to Written Test

Objective 9

a. "Check engine" light
b. Diagnostic data link
c. Electronic control analyzer and programmer (Caterpillar)
d. Electronic control module
e. Electronic distributor unit
f. Electronic unit injector
g. Ignition control module
h. Programmable read only memory

Objective 10

a. 8
b. 9
c. 1
d. 10
e. 6
f. 4
g. 5
h. 2
i. 3
j. 12

Objective 11

Any four of the following:
a. Cylinder faults
b. Injector faults
c. Temperature out of normal range
d. Pressure out of normal range
e. Speeds out of normal range
f. Fluid levels below normal
g. Sensor voltage above or below normal or shorted
h. Current above or below normal open or grounded

Objective 12

a. S
b. S
c. NS
c. S

Unit 3-C

Electronic Fuel Injection Diagnosis and Repair

Prerequisites:
None

Learning Activities Sheet

Student Name ______________________________

Place a checkmark in the appropriate box as you complete each of the steps below.

☐	1.	**Take**	Pretest provided by instructor. After test has been evaluated, follow instructor's recommendations.
☐	2.	**Read**	Objective Sheet.
☐	3.	**Study**	Information Sheet, Objectives 1 through 12.
☐	4.	**View**	Optional Videotape entitled "How to Troubleshoot Electrical Shorts and Grounds".
☐	5.	**Observe**	Demonstration of procedures to be used in completing Job Sheet 1.
☐	6.	**Do**	Job Sheet 1, "Inspect, and Test Power and Ground Circuits and Connections; Determine Needed Repairs".
☐	7.	**Stop**	Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 8. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 1 and repeat steps 5 through 7.
☐	8.	**Read**	Student Supplement 1, "SAE Fault Codes".
☐	9.	**Observe**	Demonstration of procedures to be used in completing Job Sheet 2.
☐	10.	**Do**	Job Sheet 2, "Check Diagnostic Trouble Codes Using Scan Tools and Technical Information; Determine Needed Repairs".
☐	11.	**Stop**	Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 12. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 2 and repeat steps 9 through 11.

☐ 12. **Observe** Demonstration of procedures to be used in completing Job Sheet 3.

☐ 13. **Do** Job Sheet 3, "Inspect and Replace Electrical Connectors, Terminals, Seals, and Locks".

☐ 14. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 15. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 3 and repeat steps 12 through 14.

☐ 15. **Observe** Demonstration of procedures to be used in completing Job Sheet 4.

☐ 16. **Do** Job Sheet 4, "Access Engine Parameters; Monitor or Change as Requested by Customer".

☐ 17. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 18. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 4 and repeat steps 15 through 17.

☐ 18. **Observe** Demonstration of procedures to be used in completing Job Sheet 5.

☐ 19. **Do** Job Sheet 5, "Remove, Inspect, and Rebuild or Replace a Fuel Transfer Pump".

☐ 20. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 21. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 5 and repeat steps 18 through 20.

☐ 21. **Observe** Demonstration of procedures to be used in completing Job Sheet 6.

☐ 22. **Do** Job Sheet 6, "Remove, Inspect, Reinstall, and Adjust Electronic Unit Injectors; Determine Needed Repairs".

☐ 23. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 24. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 6 and repeat steps 21 through 23.

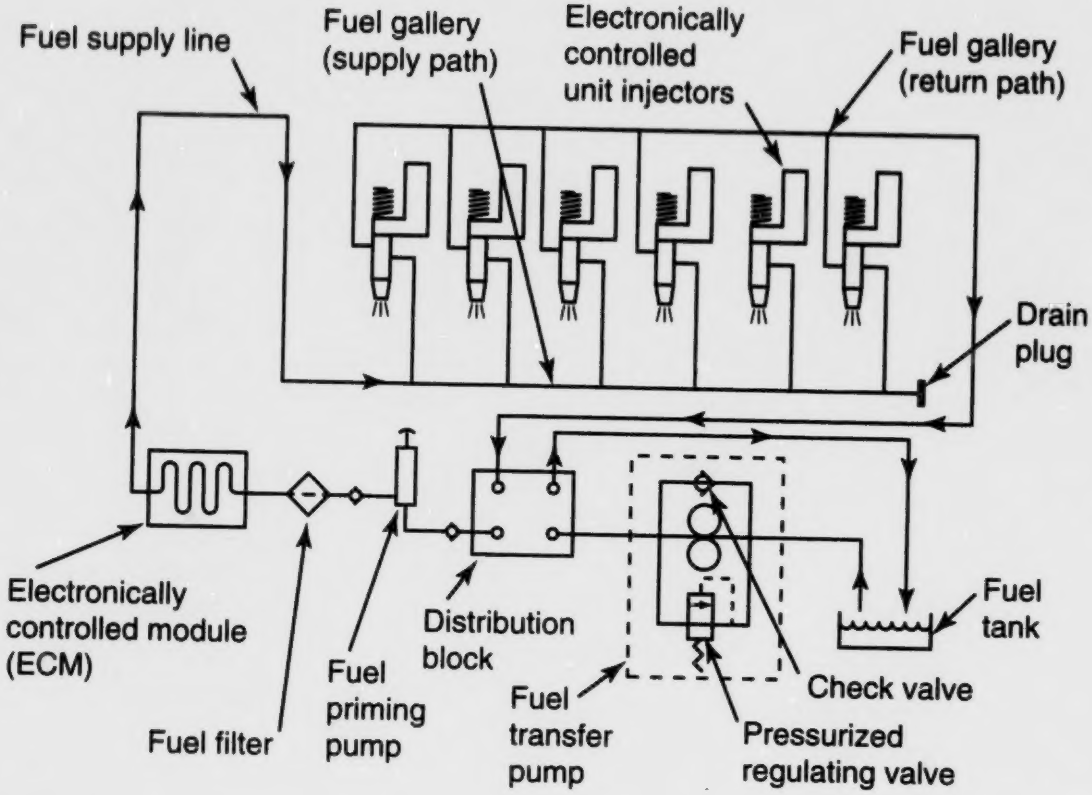
☐ 24. **Check** With instructor for any additional assignments to be completed.

☐ 25. **Take** Posttest provided by instructor. After test has been evaluated, follow instructor's recommendations.

☐ 26. **Stop** Have instructor evaluate your unit performance. If the evaluation is satisfactory, proceed to next learning activities sheet. If evaluation is not satisfactory, ask instructor for further instructions.

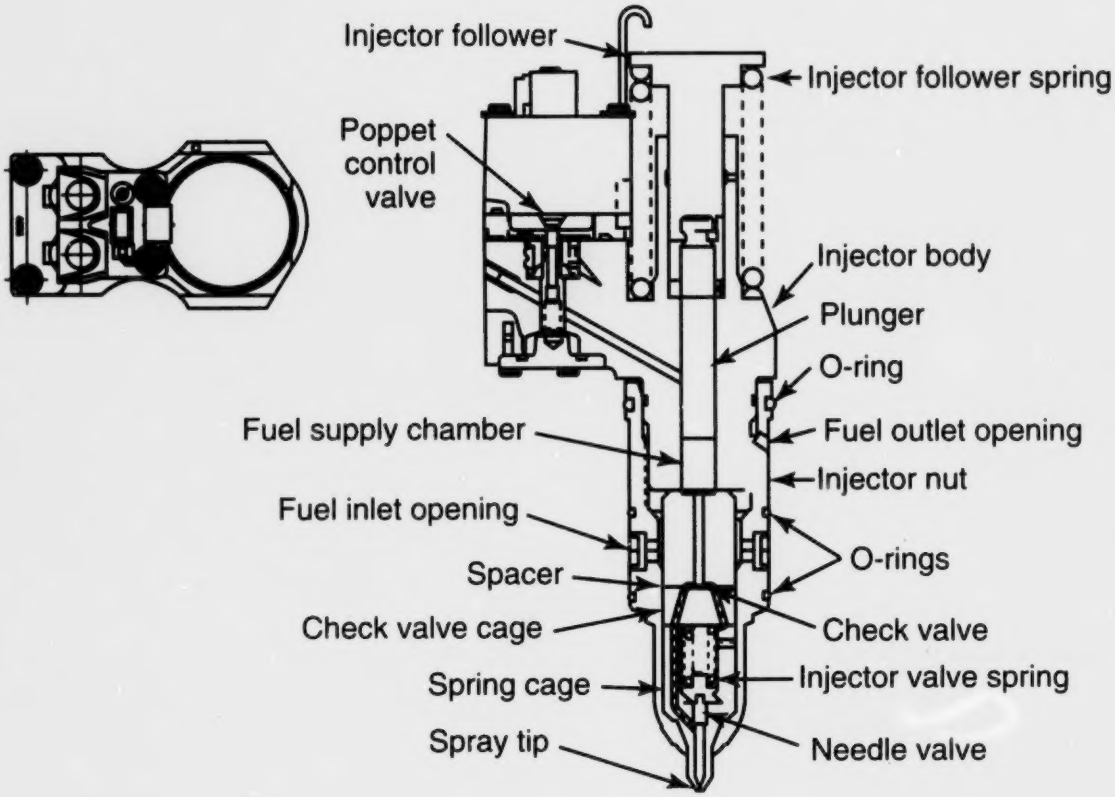
***Permission to duplicate this form is granted.**

Parts of a Typical Electronic Fuel System


Fuel supply line
Fuel gallery (supply path)
Electronically controlled unit injectors
Fuel gallery (return path)
Drain plug
Electronically controlled module (ECM)
Fuel filter
Fuel priming pump
Distribution block
Fuel transfer pump
Check valve
Pressurized regulating valve
Fuel tank

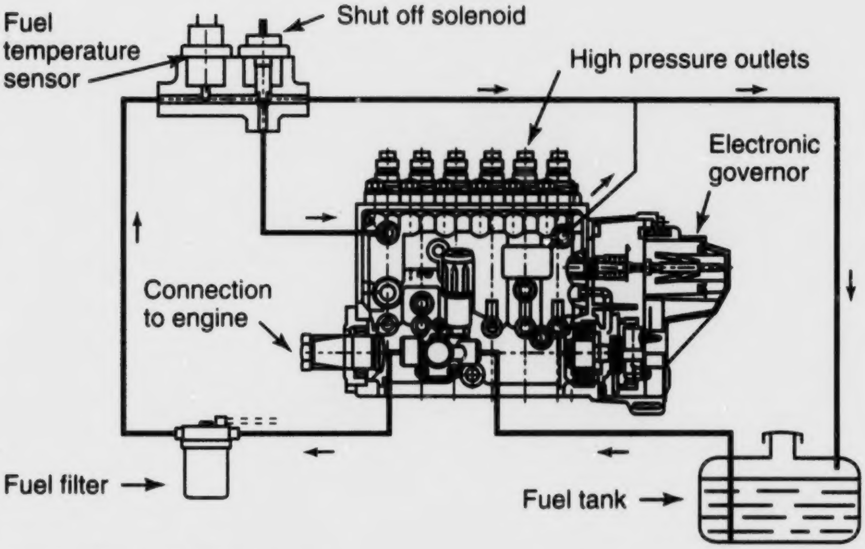
© Caterpillar Inc. Used with permission

Parts of an Electronic Unit Injector


Injector follower
Injector follower spring
Poppet control valve
Injector body
Plunger
O-ring
Fuel supply chamber
Fuel outlet opening
Injector nut
Fuel inlet opening
O-rings
Spacer
Check valve cage
Check valve
Spring cage
Injector valve spring
Spray tip
Needle valve

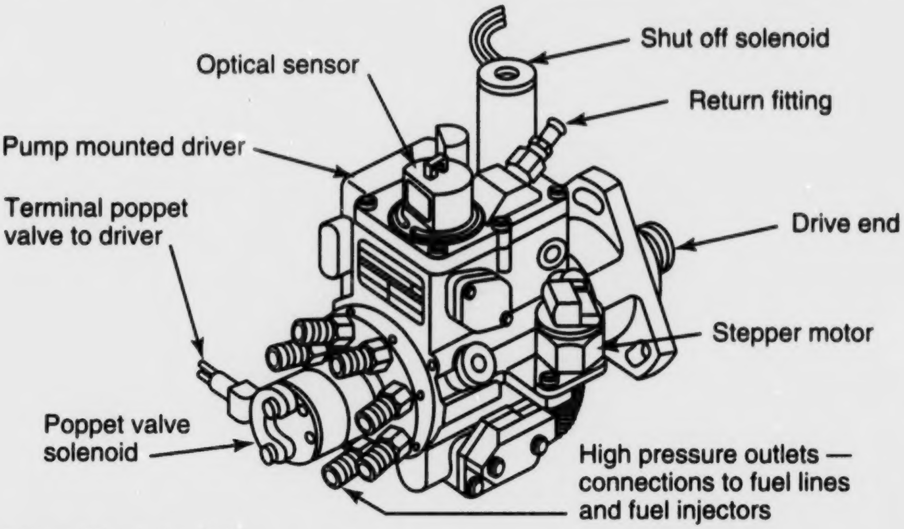
Courtesy of Detroit Diesel Corporation

Common Types of Electronic Fuel Injection Systems


Fuel temperature sensor
Shut off solenoid
High pressure outlets
Electronic governor
Connection to engine
Fuel filter
Fuel tank

Courtesy of Robert Bosch Corporation

In-line injection pump with electronic governor

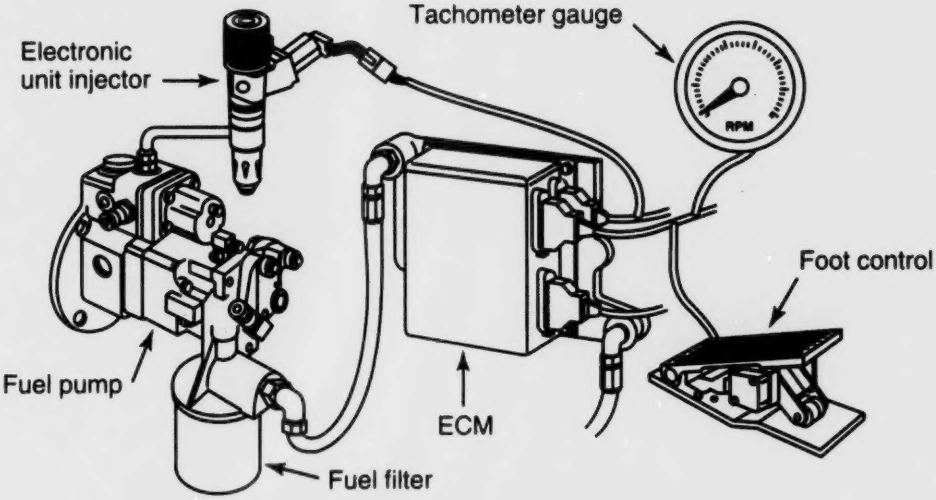

Shut off solenoid
Optical sensor
Return fitting
Pump mounted driver
Terminal poppet valve to driver
Drive end
Stepper motor
Poppet valve solenoid
High pressure outlets — connections to fuel lines and fuel injectors

Courtesy of General Motors Corporation

Distributor-type injection pump with electronic governor

Common Types of Electronic Fuel Injection Systems

(Continued)

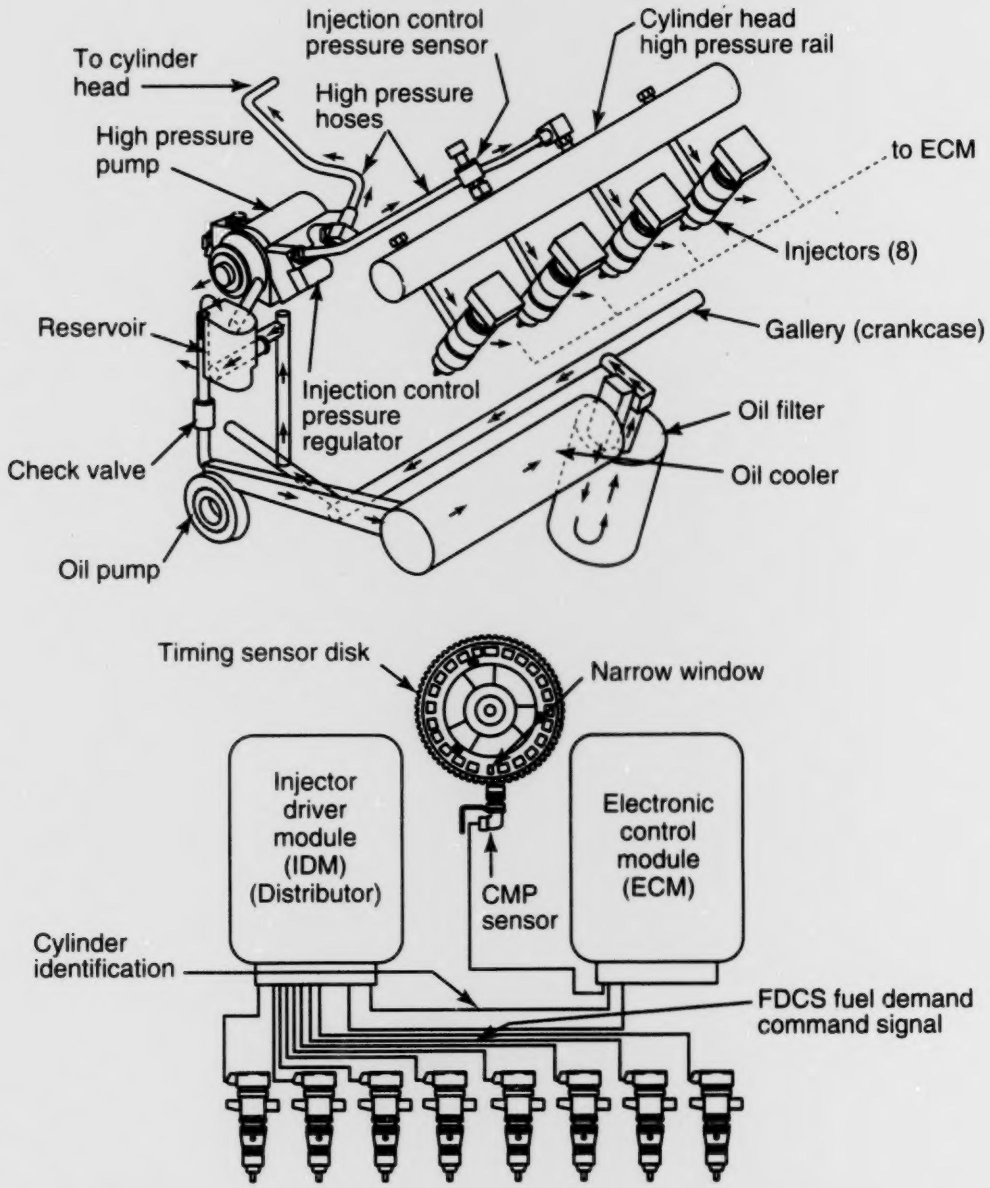

Electronic unit injector
Tachometer gauge
RPM
Foot control
Fuel pump
ECM
Fuel filter

Electronic unit injector

Courtesy of Cummins Engine Company, Inc.

Common Types of Electronic Fuel Injection Systems

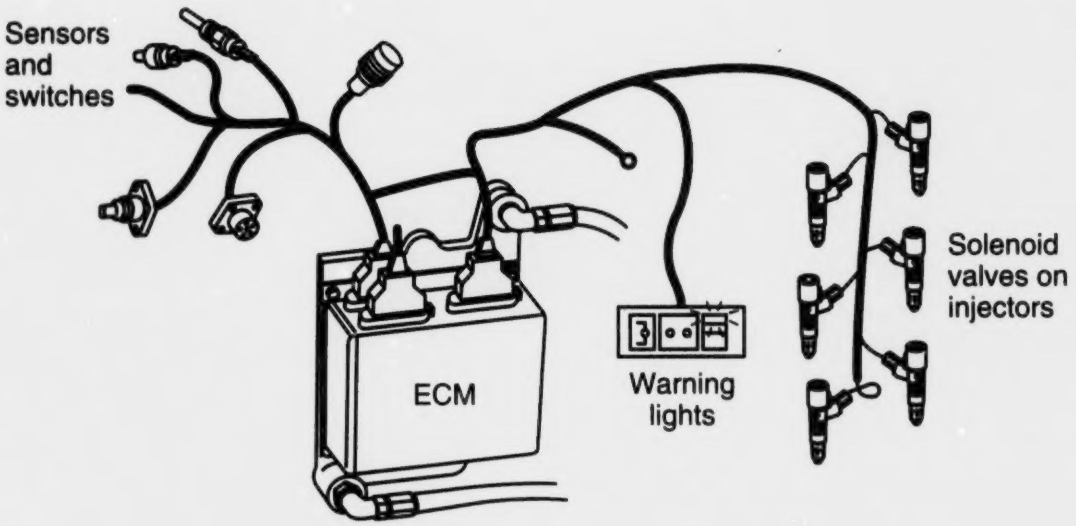
(Continued)


To cylinder head
Injection control pressure sensor
Cylinder head high pressure rail
High pressure hoses
High pressure pump
to ECM
Injectors (8)
Reservoir
Gallery (crankcase)
Injection control pressure regulator
Oil filter
Check valve
Oil cooler
Oil pump
Timing sensor disk
Narrow window
Injector driver module (IDM) (Distributor)
Electronic control module (ECM)
CMP sensor
Cylinder identification
FDCS fuel demand command signal

Hydraulically-operated and electronically-controlled unit injectors

Courtesy of Navistar International Transportation Corp.

Basic Categories of Electronic Components


Sensors and switches
ECM
Warning lights
Solenoid valves on injectors

INPUT ⟶ CONTROL ⟶ OUTPUT

Input Components

Control Component

Output Components

Unit Contents

Teacher Components

Teacher Page

Suggested Activities 4C–3

Written Test 4C–7

Answers to Written Test 4C–15

Learning Activities Sheet 4C–17

Transparency Masters

1—Diesel Fuel Combustion Reaction 4C–19
2—Greenhouse Effect 4C–21
3—Acid Rain 4C–23
4—Ozone Shield 4C–25
5—Smog 4C–27

Student Components

Student Page

Objective Sheet 4C–3

Information Sheet 4C–5

Job Sheets

1—Check Vehicle for Presence and Operation of Emission Control Devices 4C–19
2—Check Vehicle for Fuel Type and Appropriate Application 4C–23
3—Test Vehicle for Excessive Exhaust Smoke 4C–27
4—Check Vehicle for Noise Abatement Devices 4C–31

Suggested Activities

Instructional Plan

Preparation

- Read the unit carefully and plan for instruction.
- Review "Teaching Suggestions." Plan for classroom activities.
- Plan your presentation to take advantage of student learning styles and to accommodate special-needs students.
- Prepare classroom. Put up posters and charts and display articles and other references related to this unit.
- Obtain films, videotapes, and other resources to supplement instruction of this unit. See "Resources Used in Developing This Unit" and "Suggested Supplemental Resources" for more information.
- For self-paced instruction, review Learning Activities Sheet. Modify as appropriate to include additional activities and/or resources available in your classroom. Make one copy for each student.
- Make transparencies from the transparency masters included in this unit. These appear in the teacher edition only.

Delivery and Application

Unit Introduction (self-paced instruction)

- Provide student with Learning Activities Sheet and unit of instruction.
- Review unit contents with student.
- Have the student complete the steps in the learning activities sheet.

Unit Introduction (group instruction)

- Provide students with unit of instruction.
- Discuss unit and specific objectives.
- Discuss the information sheet. Implement teaching plan to localize, supplement, and personalize the unit. Reinforce basic academic and workplace skills when applicable.
- Discuss and demonstrate the job sheets. Make sure all required tools, equipment, and materials are available. Review with students the criteria for evaluation of these activities and the rating scale that will be used to indicate job performance.

Suggested Activities

Teaching Suggestions

- Have students search at the library or on the Internet for more information about emissions and other environmental issues. They could also investigate how diesel engine manufacturers (or manufacturers of related components) are addressing these issues. Many new products are developed specifically to help solve current environmental problems. Have students share their information with the class by giving informal oral reports or class discussions.

- You may want to start a resource file on environmental issues impacting on diesel technology that students can use to read about current technology. These may be newspaper, magazine, or industry journal articles that you and your students read and save. This can help keep your curriculum timely and relevant.

- Provide students with up-to-date information about any new legislation that will affect emission laws. Discuss how these laws impact on their jobs. Also provide copies of the Federal Clean Air Act for students to see. Check the EPA office in your region for more information. You can find them at their Internet home page at: http://www.epa.gov/ or write to the national headquarters at:

  Environmental Protection Agency
  401 M Street, SW
  Washington, D. C. 20460

- Invite a guest speaker to talk to the class about environmental issues affecting diesel technology and answer any technical questions the students may have. Possible speakers would be local science teachers, university extension agents, federal or state employees involved in interpreting/enforcing environmental laws, or diesel (or automobile) industry representatives or trainers experienced in this area.

Evaluation

- Make copies of the written test. Add or modify test items as needed. The written test serves as both a pretest and posttest to assist in measuring each student's competency gains.

- Give and evaluate pretest. Modify lesson plan to include additional instruction for those areas where students were deficient.

- Evaluate the job sheets. When the student is ready to perform a specific task, obtain a copy of the job sheet which may be found in the student edition. Then observe the student performing the procedure.

  Process evaluation—Place a mark in the box to the left of each designated checkpoint if the student has satisfactorily completed the process step(s) for each checkpoint area. If the student is unable to complete the procedure correctly, have the student review the materials and try again.

Product evaluation—Once the student has satisfactorily completed the procedure, rate the student product (outcome) using the criteria that are provided as part of the job sheet. If the student's product is unacceptable, have the student review the materials and submit another product for evaluation.

Two sample performance evaluation keys have been provided below. Many other keys are available. Select one rating (grading scale) that best fits your program needs.

Sample A

4—**Skilled**—Can perform job with no additional training.
3—**Moderately skilled**—Has performed job during training program; limited additional training may be required.
2—**Limited skill**—Has performed job during training program; additional training is required to develop skill.
1—**Unskilled**—Is familiar with process, but is unable to perform job.
0—**No exposure**—No information or practice provided during training program.

Sample B

Yes—Can perform job with no additional training.
No—Is unable to perform job satisfactorily.

- Give and evaluate the posttest.
- Meet individually with students to evaluate their progress through this unit of instruction and indicate to them possible areas of improvement.
- Reteach and retest as required.

Resources Used in Developing This Unit

Print Media

- Clark, Elton, et al. *Diesel Fundamentals.* Stillwater, OK: Mid-America Vocational Curriculum Consortium, Inc., 1988.
- Dagel, John F. *Diesel Engine and Fuel System Repair*, 3rd ed. Upper Saddle River, NJ: Prentice Hall, 1994.
- Espenschied, Roland F. *Diesel Engines.* Athens, GA: American Association for Vocational Instructional Materials, 1990.

Suggested Supplemental Resources

Print Media

- *ASE Test Prep Series*—Medium/Heavy Duty Truck, 2nd ed. (Diesel Engines). Albany, NY: Delmar Publishers, 2002.

  Also available in CD ROM format

Suggested Activities

- Bennett, Sean. *Medium/Heavy Duty Truck Engines, Fuel and Computerized Management Systems*. Albany, NY: Delmar Publishers, 1999.
- Bennett, Sean. *Today's Technician: Medium/Heavy Duty Truck Diesel Engines*. Albany, NY: Delmar Publishers, 2001.

Note: Although the following resources were written for automobile applications, much of the information is relevant to diesel engines as well, especially the new advanced emission systems that more closely resemble automobile emission systems.

- *Emission Control Systems and Components*. (P-9356) Explains General Motors valves, catalytic converters, and oxygen sensors. 94-page manual.
- *A Technician's Guide to Automotive Emissions Systems*. 9TGES) 340-page manual from Delmar Publishers that outlines latest emission control systems and standards.

The above are available from:

Automotive Service Association
P.O. Box 929
Bedford, TX 76095-0929
Phone: 800-272-7467 or 817-283-6205 or Fax: 817-685-0225
www.asashop.com

Electronic Media

- *Understanding and Testing Emission Control Devices* (87-1) videotape (VHS)—GMC Truck. Available from:

Regan Productions, Inc.
Service Video Library
19730 Ralston
Detroit, MI 48203
313-368-3000

Note: Although the following resources were written for automobile applications, much of the information is relevant to diesel engines as well, especially the new advanced emission systems that more closely resemble automobile emission systems.

- *Engine Fuel and Emission Systems*. (VRM-8664) Describes Ford carburetion, fuel injection, and emission systems. 1 hour, 55 minute videotape.

Automotive Service Association
P.O. Box 929
Bedford, TX 76095-0929
Phone: 800-272-7467 or 817-283-6205 or Fax: 817-685-0225
www.asashop.com

Written Test

Name ______________________________

Date ______________________ Score __________

Objective 1

Match the terms with their definitions. Definitions continue on the next page. Write your answers in the blanks provided.

1. Abatement
2. Acid rain
3. Air pollution episode
4. Ambient air
5. Atmosphere
6. Carcinogen
7. Clean fuels
8. Combustion
9. Emission
10. Emission standard
11. Environment
12. Fluorocarbons (FCs)
13. Fossil fuel
14. Fuel efficiency
15. Hydrocarbons
16. National ambient air quality standards (NAAQS)
17. Noise
18. Non-attainment area
19. Particulate
20. Pollutant
21. Pollution
22. Smoke
23. Toxic
24. Volatile
25. Volatile organic compound (VOC)

_____ a. Mass of air surrounding the earth held by the force of gravity

_____ b. Readily vaporized

_____ c. Organic compounds of hydrogen and carbon, such as those occurring in fossil fuels

_____ d. Chemical process of burning that releases heat, light and chemical by-products

_____ e. Any introduced gas, liquid, or solid that makes a resource unfit for a specific purpose

_____ f. Any organic compound that contributes to smog

_____ g. Proportion of useful energy to total energy released upon combustion of a fuel

_____ h. Any unconfined portion of the atmosphere; the outside air

_____ i. Level of pollutants in the outside air that cannot be exceeded during a specified time in a specified geographical area as established by EPA

_____ j. Atmospheric moisture falling to the ground as rain, snow, ice, or fog that has a pH of less than 5.6

_____ k. Capable of causing death, disease, or birth defects if ingested or absorbed; hazardous even at low concentration

_____ l. Fine liquid or solid particles such as dust, smoke, mist, fumes, or smog found in air or emissions

_____ m. Energy source derived from ancient organic (carbon-based) remains

_____ n. Any of a number of organic compounds analogous to hydrocarbons in which one or more hydrogen atoms are replaced by fluorine

_____ o. Reducing or eliminating environmental hazards

_____ p. Pollutant discharged into the air

_____ q. Blends or substitutes for petroleum-based fuels

_____ r. Area that does not meet one or more of the NAAQS for the criteria pollutants designated in the Clean Air Act

_____ s. Substance that produces cancer

_____ t. Sum of all external conditions affecting the life, development, and survival of an organism

_____ u. Presence of matter or energy whose nature, location, or quantity produces undesirable environmental effects

Objective 2 Identify the chemical components involved in the diesel fuel combustion reaction.

$$\underbrace{C_xH_yS_z}_{\text{a.}} + \underbrace{O_2 + N_2}_{\text{b.}} \rightarrow \underbrace{CO_2 + H_2O + N_2 + O_2}_{\text{c.}} + \underbrace{NO_x + HC + CO + SO_x + C}_{\text{d.}}$$

a. ______________________________

b. ______________________________

c. ______________________________

d. ______________________________

Objective 3

Match exhaust emissions with their characteristics. Write your answers in the blanks provided.

1. Carbon dioxide (CO_2)
2. Carbon monoxide (CO)
3. Hydrocarbons (HC)
4. Oxides of nitrogen (NO_x)
5. Oxides of sulfur (SO_x)
6. Ozone (O_3)
7. Particulate matter (PM)

_____ a. Formed through complex chemical reactions between precursor emissions of volatile organic compounds and nitrogen oxides in the presence of sunlight. Rate of reaction is related to temperature and intensity of sunlight.

_____ b. Is non-toxic, but is associated with global warming, a separate environmental issue

_____ c. Collective name for over 100 different compounds made up of carbon and hydrogen

_____ d. Combines with other chemicals to create acids that fall to earth as acid rain

_____ e. Collective name for very small substances deposited on a filter as diluted exhaust is passed through it. Main constituents include carbon particles, heavy hydrocarbons from fuel and lube oil, sulfates, and ash.

_____ f. Enters the bloodstream and reduces the delivery of oxygen to the body's organs and tissues

_____ g. Product of oxidation of the fuel-bound sulfur during the combustion process

Objective 4

Distinguish between the types of smoke emissions by placing a "B" next to characteristics of black smoke and a "W" next to characteristics of white smoke.

_____ a. Is an issue under cold conditions at low loads

_____ b. Made up of carbon particles that escape the combustion process which then block the passage of light through the exhaust

_____ c. Made up of particles of essentially colorless liquid (unburned by hydrocarbons and water vapor) which reflect or refract light

_____ d. Is typically emitted during accelerations and at high loads

Written Test

Objective 5

Complete statements concerning environmental issues affected by emissions by circling the correct answers.

a. Greenhouse gases and global warming

- A layer of carbon dioxide and other gases above the earth's surface acts like a **(glass, mirror)** on top of a greenhouse.
- Many scientists believe that an **(increase, decrease)** in the atmospheric concentration of carbon dioxide can eventually cause an increase in the earth's surface temperature—global warming.
- Burning **(more, fewer)** carbon products including fossil fuels, plants, and animal wastes should result in less carbon dioxide production and reduced greenhouse effect.
- Use of **(clean, petroleum)** fuels should also help slow the atmospheric buildup of carbon dioxide and other greenhouse gases.

b. Acid rain

- Occurs when oxides of sulfur and nitrogen combine with atmospheric moisture. Acid rain is formed.
  - Sulfur dioxide combines with water to produce (**sulfuric**, **nitric acid**).
  - Nitrogen dioxide combines with water to produce (**sulfuric**, **nitric**) acid.
- Winds **(can, cannot)** transport airborne acid particles hundreds of miles across state and national borders.
- **(Reduced, Increased)** emissions of sulfur and nitrogen oxides should help with acid rain problem.

c. Stratospheric ozone depletion

- The ozone shield is a layer of **(atmospheric oxygen, ozone)** in the stratosphere 6 to 30 miles above the earth that protects all earth organisms from dangerous ultraviolet radiation from the sun.
- It is being depleted by certain **(carbon, chlorine)** compounds including chlorofluorocarbons (CFC), as well as nitrogen oxides from combustion of fossil fuels.

d. Smog

- Smog is formed by the action of **(sunlight, heat)** on oxides of hydrogen, hydrocarbons, and ground level ozone, its major component.
- It is considered the **(least, most)** serious air quality problem in the U.S. today.
- Smog is a severe irritant responsible for **(vomiting, coughing)**.
- It is a serious problem in most **(rural, urban)** areas.
- Smog is more severe in **(sunny, cloudy)** locations.

Objective 6

Complete statements concerning the federal Clean Air Act by circling the correct answers.

a. The Clean Air Act regulates **(air emissions, use pollution)** from both stationary and mobile sources.

b. This Act was originally passed into law in **(1970, 1985)**.

c. The Act gave primary responsibility for regulating pollution from power plants, factories, and other "stationary sources" to **(state and local, federal)** government(s).

d. The Act gave primary responsibility for regulating "mobile sources," which includes cars, trucks, buses, and aircraft, to **(OSHA, EPA)**.

e. Regulations **(limiting, increasing)** the amount of sulfur in diesel fuel took effect in 1993.

f. The 1990 Act set specific emission standards for hydrocarbons and for diesel **(hydrogen particles, particulate matter)**.

g. The 1990 Act **(does, does not)** regulate emissions from off-highway vehicles.

Written Test

Objective 7

Match tests for emissions with their correct descriptions. Write your answers in the blanks provided.

1. "High-tech" tests for new vehicles
2. Inspection and maintenance tests (I/M)
3. Onboard diagnostics (OBD) systems
4. Remote sensing tests

_____ a. Take a "snapshot" of a vehicle's emissions as it passes by a sensor located on the side of the road; used as a supplemental test primarily to identify high-emitting ("super-dirty") vehicles; measures hydrocarbons and carbon monoxide; cannot measure nitrogen oxides or evaporative emissions

_____ b. Used to identify faulty emission controls and ensure their repair; involves two tests: (1) tailpipe test of exhaust emissions; (2) check to ensure that critical emission control components are present and functional

_____ c. Involves sophisticated tests of vehicles being operated on a dynamometer through a driving cycle (includes acceleration and deceleration); measure exhaust emissions including hydrocarbon, carbon monoxide, and nitrogen oxide; also measures evaporative emissions including hydrocarbons

_____ d. Use vehicle computers to monitor emission control and to alert drivers and technicians about emission problems

Objective 8

Describe efforts to improve emissions.

a. What has recently been done:

____

____

____

____

____

b. What else can be done:

____

____

____

____

____

4-9

Objective 9

Match alternative/clean fuels with their correct descriptions. Write your answers in the blanks provided.

1. Alcohols	3. Liquid petroleum gas
2. Electricity	4. Natural gas

_____ a. This is a by-product of petroleum refining and natural gas production; emit less ozone-forming hydrocarbons than conventional fuels.

_____ b. Methanol and ethanol are high-octane liquid fuels.

_____ c. This alternative/clean fuel is also being used on vehicles with diesel fuel as a backup and for firing.

_____ d. Battery-powered vehicles have the potential for zero tailpipe and evaporative hydrocarbon and nitrogen oxide emissions.

Objective 10

List three methods for reducing noise levels.

a. ______________________________

b. ______________________________

c. ______________________________

***Permission to duplicate this test is granted.**

Answers to Written Test

Objective 1

a. 5
b. 24
c. 15
d. 8
e. 20
f. 25
g. 14
h. 4
i. 16
j. 2
k. 23
l. 19
m. 13
n. 12
o. 1
p. 9
q. 7
r. 18
s. 6
t. 11
u. 21

Objective 2

a. Diesel fuel
b. Air
c. Major exhaust components
d. Minor exhaust components

Objective 3

a. 6
b. 1
c. 3
d. 4
e. 7
f. 2
g. 5

Objective 4

a. W
b. B
c. W
d. B

Objective 5

a.
- Glass
- Increase
- Fewer
- Clean

b.
- Sulfuric
  Nitric
- Can
- Reduced

c.
- Ozone
- Chlorine

d.
- Sunshine
- Most
- Coughing
- Urban
- Sunny

Objective 6

a. Air emissions
b. 1970
c. State and local
d. EPA
e. Limiting
f. Particulate matter
g. Does

Answers to Written Test

Objective 7

a. 4
b. 2
c. 1
d. 3

Objective 8

Answers should include the following in student's own words:

a. What has recently been done
  - Oil companies/refineries changed diesel fuel composition and reduced the sulfur level to reduce harmful emissions.
  - Vehicle manufacturers used new technology to improve performance of new vehicles.
    — They increased the use of electronic fuel injection to improve engine efficiency and thereby reduce by-products of incomplete combustion.
    — They redesigned vehicles to include computerized diagnostic systems that monitor optimal engine performance and that alert drivers and technicians about malfunctioning emission controls.
    — They increased the use of more efficient catalytic converters to reduce hydrocarbons and particulates.
  - Diesel technicians and end-users (drivers/owners) monitor and inspect vehicles to make sure that emission control devices are operating correctly as designed by the manufacturer.

b. What else can be done
  - Switch to alternative, non-petroleum fuels to reduce air toxics. This will require a great investment by vehicle manufacturers in new engine designs/redesigns, as well as a new infrastructure involving convenient alternative fueling stations.
  - Remove "super-dirty" vehicles from the road. A relatively small number of old, deteriorating, and poorly maintained vehicles are major contributors to ozone-forming hydrocarbon emissions.
  - Continue to make improvements in vehicle performance in order to use less fuel, as well as inventing new devices that can capture emissions or reconfigure emissions to be less harmful.

Objective 9

a. 3
b. 1
c. 4
d. 2

Objective 10

Any three of the following:

a. Engine redesigns, especially turbocharging and serpentine blocks
b. Tire redesigns
c. Transmission redesigns
d. Sound proofing of engine compartments
e. Sound proofing of cab
f. Fairings
g. Mufflers
  - Standard mufflers use baffles to dampen noise.
  - Electronic mufflers change frequencies of sound coming out so human ear cannot detect.

Unit 4-C Emissions

Prerequisites:
None

Learning Activities Sheet

Student Name ______________________________

Place a checkmark in the appropriate box as you complete each of the steps below.

☐ 1. **Take** Pretest provided by instructor. After test has been evaluated, follow instructor's recommendations.

☐ 2. **Read** Objective Sheet.

☐ 3. **Study** Information Sheet, Objectives 1 through 9.

☐ 4. **Research** Online resources regarding government regulations on air emissions. Visit www.epa.gov as one of your resources.

☐ 5. **Observe** Demonstration of procedures to be used in completing Job Sheet 1.

☐ 6. **Do** Job Sheet 1, "Check Vehicle for Presence and Operation of Emission Control Devices".

☐ 7. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 8. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 1 and repeat steps 5 through 7.

☐ 8. **Observe** Demonstration of procedures to be used in completing Job Sheet 2.

☐ 9. **Do** Job Sheet 2, "Check Vehicle for Fuel Type and Appropriate Application".

☐ 10. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 11. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 2 and repeat steps 8 through 10.

☐ 11. **Observe** Demonstration of procedures to be used in completing Job Sheet 3.

Learning Activities Sheet

☐ 12. **Do** Job Sheet 3, "Test Vehicle for Excessive Exhaust Smoke".

☐ 13. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 14. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 3 and repeat steps 11 through 13.

☐ 14. **Study** Information Sheet, Objective 10.

☐ 15. **Observe** Demonstration of procedures to be used in completing Job Sheet 4.

☐ 16. **Do** Job Sheet 4, "Check Vehicle for Noise Abatement Devices".

☐ 17. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 18. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 4 and repeat steps 15 through 17.

☐ 18. **Check** With instructor for any additional assignments to be completed.

☐ 19. **Take** Posttest provided by instructor. After test has been evaluated, follow instructor's recommendations.

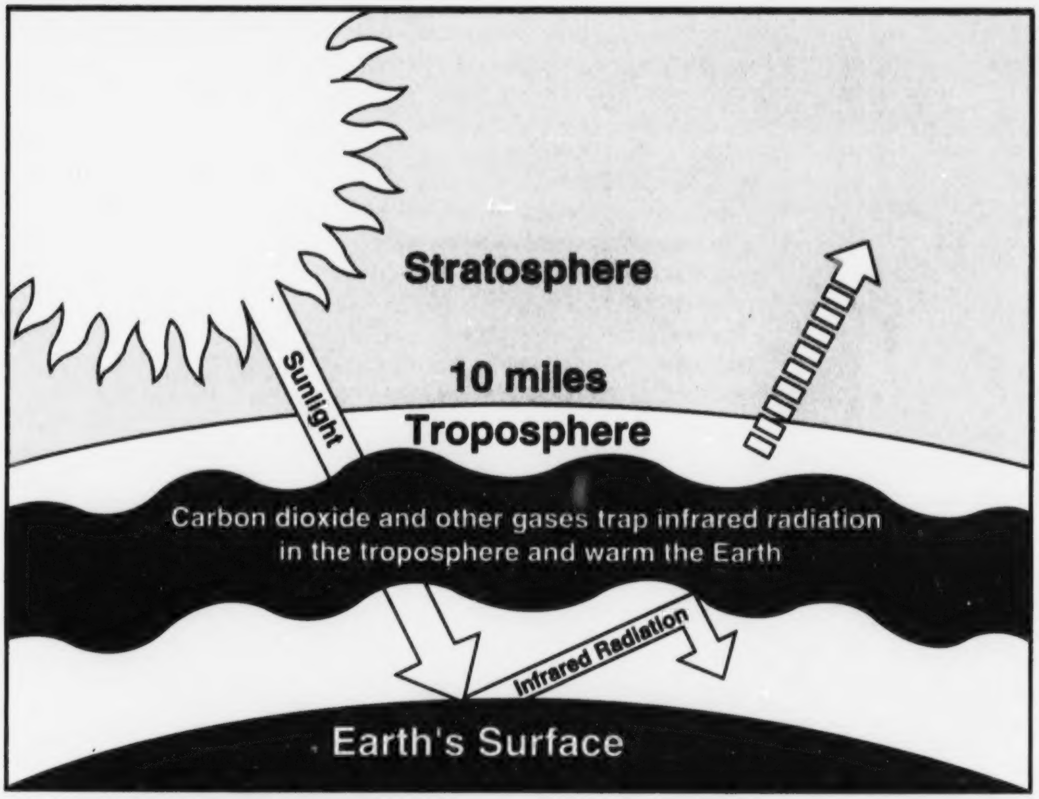
☐ 20. **Stop** Have instructor evaluate your unit performance. If the evaluation is satisfactory, proceed to next learning activities sheet. If evaluation is not satisfactory, ask instructor for further instructions.

***Permission to duplicate this form is granted.**

Diesel Fuel Combustion Reaction

$C_xH_yS_z$	Diesel fuel
+	
$O_2 + N_2$	Air
↓	
$CO_2 + H_2O + N_2 + O_2$	Major exhaust components
+	
$NO_x + HC + CO + SO_x + C$	Minor exhaust components

Greenhouse Effect


Stratosphere
Sunlight
10 miles
Troposphere
Carbon dioxide and other gases trap infrared radiation in the troposphere and warm the Earth
Infrared Radiation
Earth's Surface

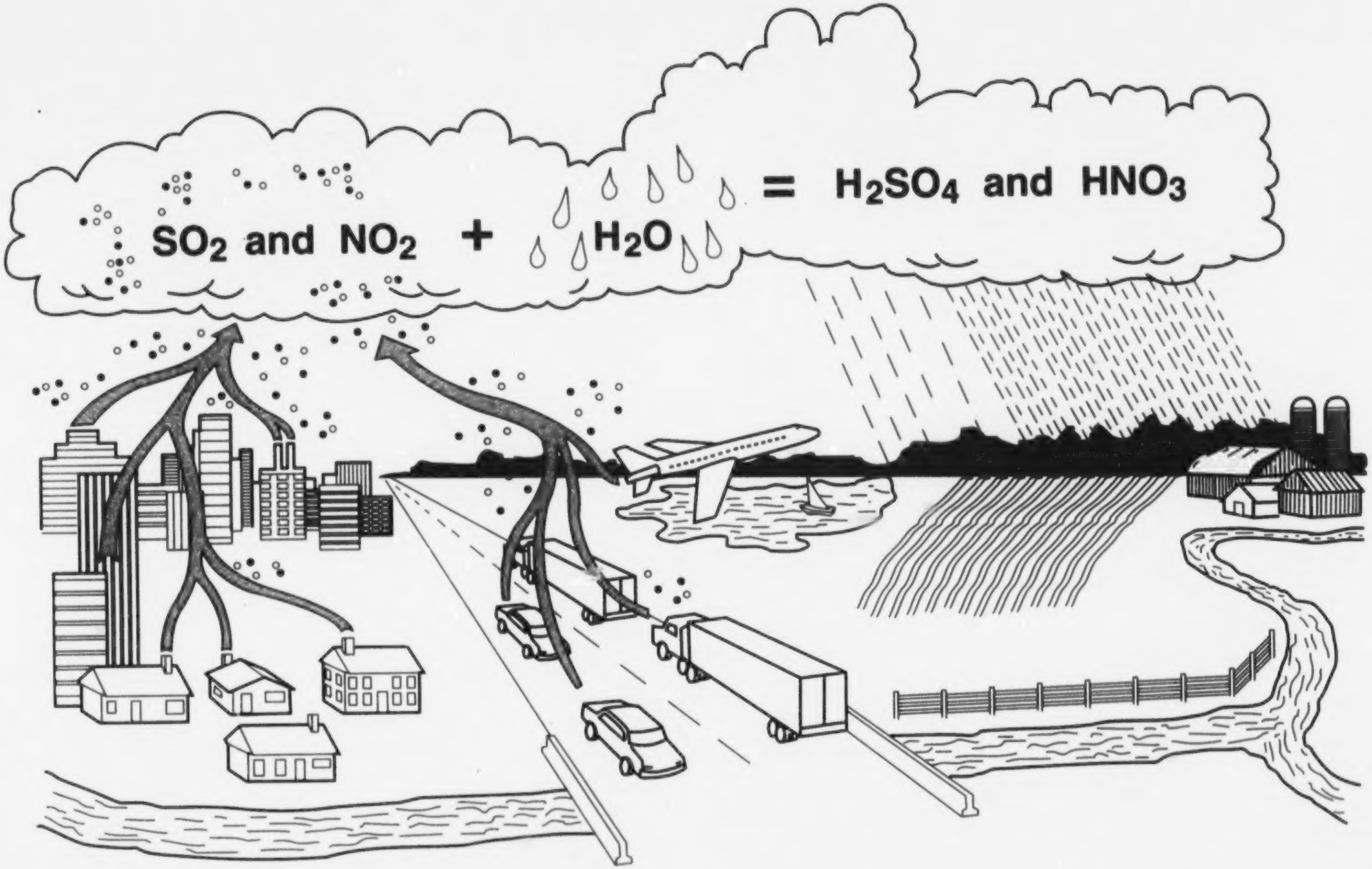
Courtesy of U.S. Environmental Protection Agency

The Greenhouse Effect Traps Solar Heat

BEST COPY AVAILABLE

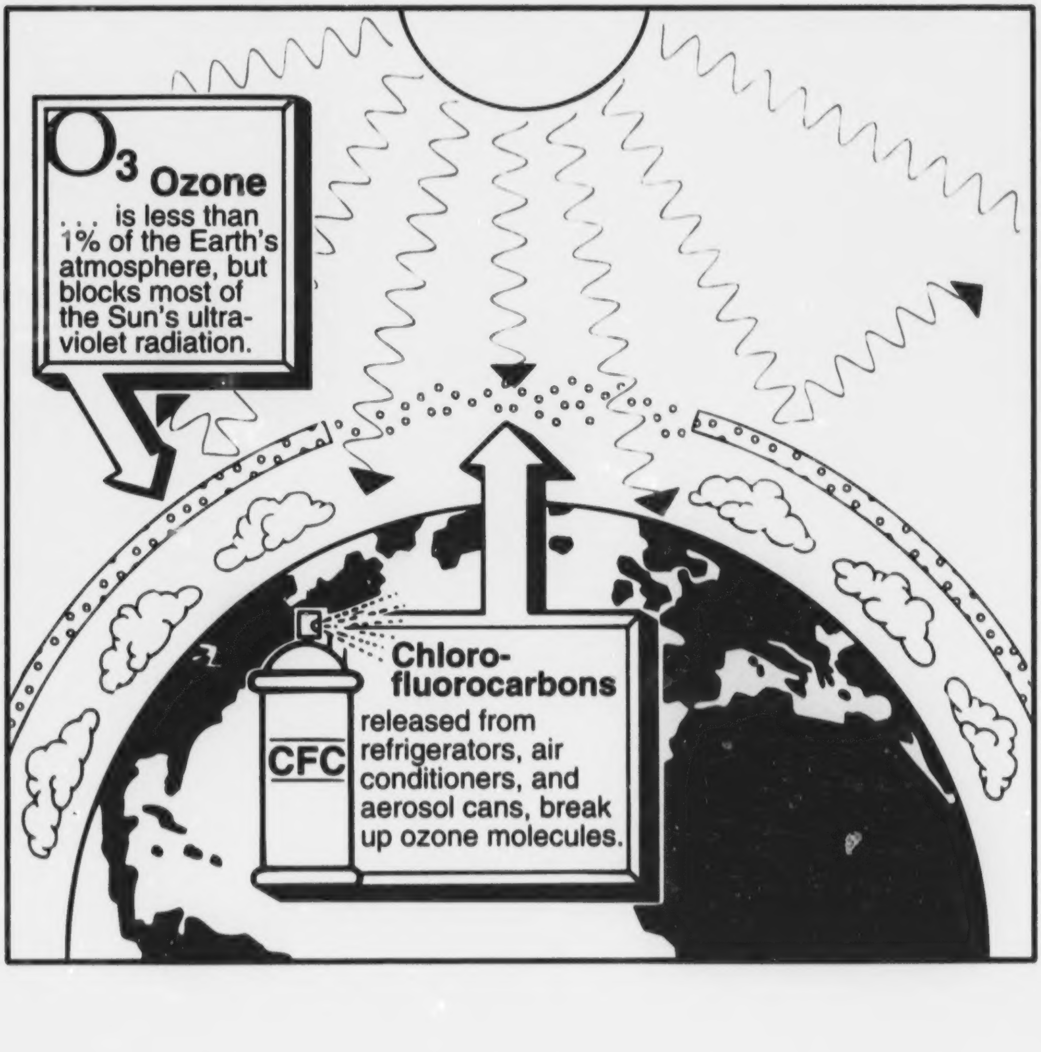
TM 2

Acid Rain

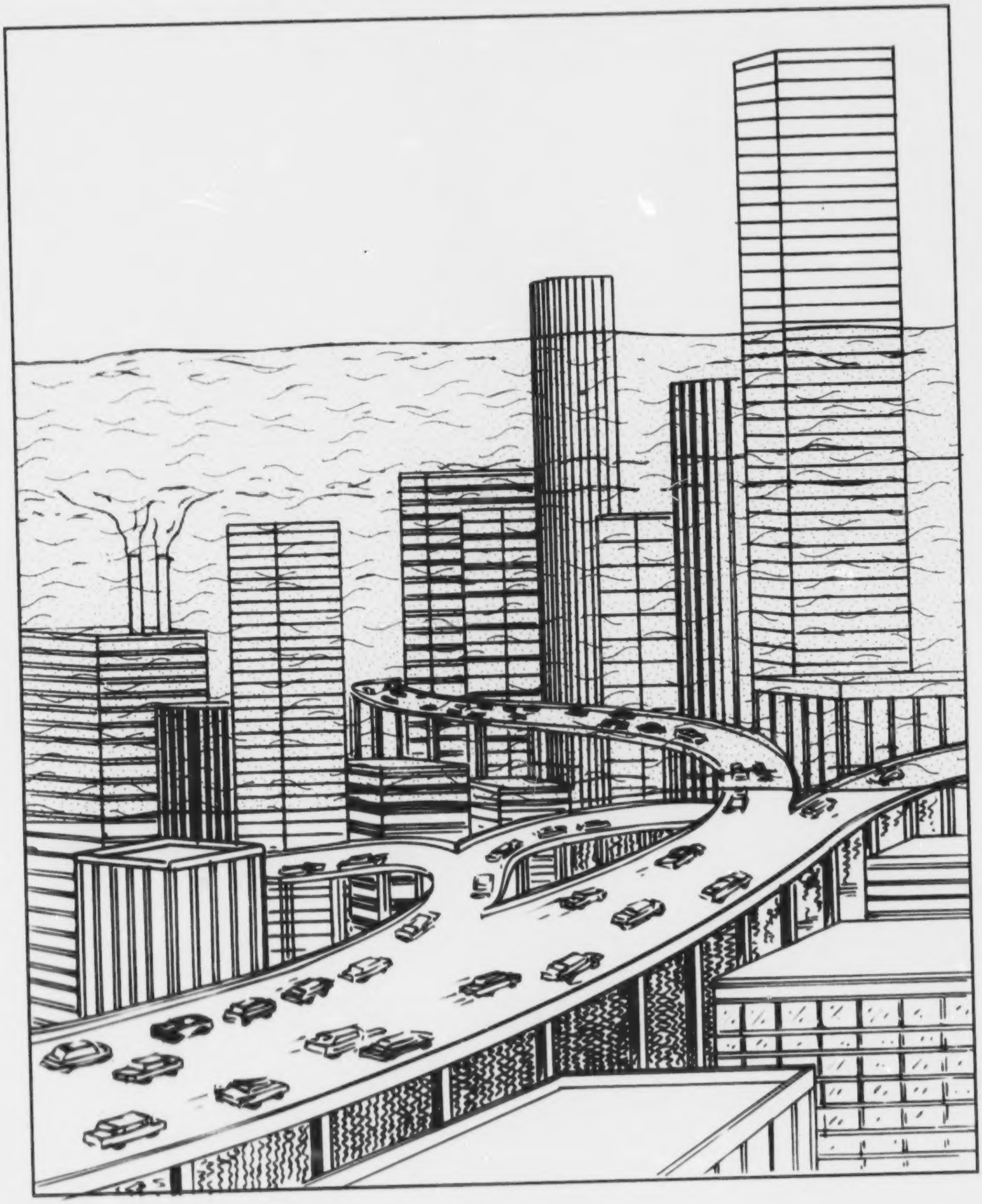

SO_2 and NO_2 + H_2O = H_2SO_4 and HNO_3

BEST COPY AVAILABLE

Ozone Shield


O_3 Ozone
. . . is less than 1% of the Earth's atmosphere, but blocks most of the Sun's ultraviolet radiation.
CFC
Chlorofluorocarbons
released from refrigerators, air conditioners, and aerosol cans, break up ozone molecules.

Smog



TM 5

Unit 1-D General Engine Diagnosis

Unit Contents

Teacher Components

Teacher Page

Suggested Activities 1D–3

Answers to Assignment Sheets 1D–9

Written Test 1D–11

Answers to Written Test 1D–15

Learning Activities Sheet 1D–17

Student Components

Student Page

Objective Sheet 1D–3

Information Sheet 1D–5

Student Supplement

1—SAE Codes 1D–13

Assignment Sheets

1—Conduct an Operator Survey for Engine Diagnosis 1D–25
2—Interpret SAE Code Identifiers 1D–29

Job Sheets

1—Check Air Intake System for Restrictions 1D–31
2—Check Exhaust Back Pressure 1D–35
3—Check Crankcase Pressure 1D–39
4—Check Oil Pressure 1D–43
5—Load Test an Engine with a Dynamometer 1D–47
6—Locate a Misfiring Cylinder 1D–51
7—Locate an Active Fault Code 1D–55

Suggested Activities

Instructional Plan

Preparation

- Read the unit carefully and plan for instruction.
- Review "Teaching Suggestions." Plan for classroom activities.
- Plan your presentation to take advantage of student learning styles and to accommodate special-needs students.
- Prepare classroom. Put up posters and charts and display articles and other references related to this unit.
- Obtain films, videotapes, and other resources to supplement instruction of this unit. See "Resources Used in Developing This Unit" and "Suggested Supplemental Resources" for more information.
- For self-paced instruction, review Learning Activities Sheet. Modify as appropriate to include additional activities and/or resources available in your classroom. Make one copy for each student.

Delivery and Application

Unit Introduction (self-paced instruction)

- Provide student with Learning Activities Sheet and unit of instruction.
- Review unit contents with student.
- Have the student complete the steps in the learning activities sheet.

Unit Introduction (group instruction)

- Provide students with unit of instruction.
- Discuss unit and specific objectives.
- Discuss the information sheet. Implement teaching plan to localize, supplement, and personalize the unit. Reinforce basic academic and workplace skills when applicable.
- Discuss the assignment sheets. Review with students the criteria for evaluation of these activities.

Suggested Activities

- Discuss and demonstrate the job sheets. Make sure all required tools, equipment, and materials are available. Review with students the criteria for evaluation of these activities and the rating scale that will be used to indicate job performance.

Teaching Suggestions

- Demonstrate the dynamometer (if available) and discuss the diagnostic performance tests that can be made on it.

- Have students locate on an actual vehicle the electronic components involved in engine diagnosis, such as the ECM, sensors, and electronic warning devices. Have them show how the parts are connected.

- Discuss the different manufacturers' methods of storing and retrieving computer fault information. Show the different parts involved and how they are similar and how they are different.

- Obtain from manufacturers up-to-date service manuals, bulletins, troubleshooting guides, videos, and brochures that explain electronic engine diagnosis. Provide for students so they can appreciate current technology.

- Demonstrate how to connect the diagnostic equipment. Also discuss how manufacturers may have slight modifications for their equipment.

- Discuss the safety hazards associated with working on electronic engines. Personalize the information by relating any experiences you have had with accidents or mishaps that occurred when working around electronics.

Evaluation

- Make copies of the written test. Add or modify test items as needed. The written test serves as both a pretest and posttest to assist in measuring each student's competency gains.

- Give and evaluate pretest. Modify lesson plan to include additional instruction for those areas where students were deficient.

- Evaluate the assignment sheets. Rate the student using the criteria listed on each assignment sheet. See Answers to Assignment Sheets for correct answers where applicable. If the student's performance is unacceptable, have the student review the appropriate materials and complete the assignment again.

- Evaluate the job sheets. When the student is ready to perform a specific task, obtain a copy of the job sheet which may be found in the student edition. Then observe the student performing the procedure.

Process evaluation—Place a mark in the box to the left of each designated checkpoint if the student has satisfactorily completed the process step(s) for each checkpoint area. If the student is unable to complete the procedure correctly, have the student review the materials and try again.

Product evaluation—Once the student has satisfactorily completed the procedure, rate the student product (outcome) using the criteria that are provided as part of the job sheet. If the student's product is unacceptable, have the student review the materials and submit another product for evaluation.

Two sample performance evaluation keys have been provided below. Many other keys are available. Select one rating (grading scale) that best fits your program needs.

Sample A

4—**Skilled**—Can perform job with no additional training.
3—**Moderately skilled**—Has performed job during training program; limited additional training may be required.
2—**Limited skill**—Has performed job during training program; additional training is required to develop skill.
1—**Unskilled**—Is familiar with process, but is unable to perform job.
0—**No exposure**—No information or practice provided during training program.

Sample B

Yes—Can perform job with no additional training.
No—Is unable to perform job satisfactorily.

- Give and evaluate the posttest.
- Meet individually with students to evaluate their progress through this unit of instruction and indicate to them possible areas of improvement.
- Reteach and retest as required.

Resources Used in Developing This Unit

Print Media

- Clark, Elton, et al. *Diesel Fundamentals.* Stillwater, OK: Mid-America Vocational Curriculum Consortium, Inc., 1988.
- Dagel, John F. *Diesel Engine and Fuel System Repair*, 3rd ed. Upper Saddle River, NJ: Prentice Hall, 1994.
- Espenschied, Roland F. *Diesel Engines.* Athens, GA: American Association for Vocational Instructional Materials, 1990.
- *Fundamentals of Service: Engines*, 7th ed. Moline, IL: Deere and Company, 1991.

Suggested Activities

- *Rebuild Manual, Cummins Diesel 10 Litre Engines*. Columbia, IN: Cummins Engine Co., 1984.
- *Series 60 Service Manual*. Detroit, MI: Detroit Diesel Corp., 1995.
- *Service Manual, 3176B Diesel Truck Engine*. Peoria, IL: Caterpillar, Inc., 1995.
- *Service Manual, D11N Tractor*. Peoria, IL: Caterpillar, Inc., 1991.

Note: Engine manuals can be ordered through the local dealerships.

Suggested Supplemental Resources

Print Media

- *ASE Test Prep Series*—Medium/Heavy Duty Truck, 2nd ed. (Diesel Engines). Albany, NY: Delmar Publishers, 2002.

  Also available in CD ROM format
- Bennett, Sean. *Medium/Heavy Duty Truck Engines, Fuel and Computerized Management Systems*. Albany, NY: Delmar Publishers, 1999.
- Bennett, Sean. *Today's Technician: Medium/Heavy Duty Truck Diesel Engines*. Albany, NY: Delmar Publishers, 2001.

Electronic Media

- *Diesel Engine Overhaul* (VH1-67PT), 58-minute videotape—Shows a step-by-step teardown, inspection, and assembly for out-of-frame block repairs to a four-stroke cycle Cummins engine. Three parts.
- *Detroit Diesel Overhaul* (VH1-87PT), 58-minutes videotape—Shows the procedures and tips to major block rebuilding of the two-stroke cycle Detroit Diesel engine. Three parts.
- *Dirt–Engine Enemy #1* (VH1-90PT), 10-minute videotape—Shows abrasive wear from dirt on pistons, rings, cylinders, bearings, and other components.
- *Engine Diagnosis and the Cooling System* (VH1-101PT), 11-minute videotape—Discusses the steps in engine diagnosis and common cooling system problems and failures.

The above are available from:

Dana Corporation
Publication Services
P.O. Box 453
Toledo, OH 43692-0453
Phone: 419-535-4285 or Fax: 419-535-4396
www.dana.com

- *E7 Engine Overhaul, Part 1 Kit*, (5-199K). Includes video and service manual.
- *E7 Engine Overhaul* video guide book. (5-199)
- *E7 Engine Overhaul, Part 2 Kit*. (5-198K). Includes video and five guide books.

The above are available from:

Mack Trucks, Inc.
2100 Mack Boulevard
P.O. Box M
Allentown, PA 18195-5000
610-439-3011
www.mactrucks.com

Answers to Assignment Sheets

Assignment Sheet 1

Conduct an Operator Survey for Engine Diagnosis

Answers will vary depending on engine problem and operator responses. Evaluate accordingly.

Assignment Sheet 2

Interpret SAE Code Identifiers

1. a. Engine
   b. Engine coolant temperature
   c. Above normal operating range
   d. Engine is overheating

2. a. Engine
   b. Throttle position sensor
   c. Erratic, intermittent, incorrect
   d. Loose connector and/or bad sensor

3. a. Engine
   b. Injector cylinder #15
   c. Abnormal frequency, pulse width, or period
   d. Bad unit injector

4. a. Engine
   b. Knock sensor
   c. Erratic, intermittent, incorrect
   d. Loose connector and/or bad sensor

5. a. Engine
   b. Alternator voltage
   c. Above normal operating range
   d. Regulator bad

6. a. Engine
   b. Engine oil pressure
   c. Below normal operating range
   d. Insufficient oil pressure

Written Test

Name ______________________________

Date ______________________ Score __________

Objective 1

Match the terms related to engine diagnosis with their definitions. Write your answers in the blanks provided.

1. Aeration
2. Dynamometer
3. Diagnostic data link
4. Electronic control module
5. Electronic unit injector
6. Infrared thermometer
7. Manometer
8. Personality module
9. Pyrometer
10. Snapshot
11. Symptom
12. Tachometer
13. Troubleshooting

_____ a. Indication of a mechanical or electrical/electronic problem

_____ b. Contains customer-specified information concerning engine performance

_____ c. Uses an ECM-controlled, injector-mounted electric solenoid to control amount and timing of injected fuel

_____ d. Computer that processes information from engine sensors and controls the fuel injector solenoid

_____ e. Process using test instruments to locate and diagnose the cause of failure

_____ f. Device that measures high exhaust temperatures (usually over 300°F)

_____ g. Foaming caused by air mixing with a liquid, such as oil or fuel

_____ h. Device that measures engine speed

_____ i. Device that measures positive or negative pressure (vacuum)

_____ j. Device that measures engine power output by applying a load to the engine

_____ k. ECM recordings at time and operating parameters when a fault occurs

_____ l. Allows shop test equipment to "plug into" the ECM

Written Test

Objective 2

Arrange in order the steps used in evaluating engine performance by writing the sequence number in front of each of the five evaluation steps.

_____ a. Visually inspect the vehicle.

_____ b. Survey the operator.

_____ c. Locate symptom(s) in manufacturer's troubleshooting chart.

_____ d. Use computer diagnostic abilities to test the vehicle.

_____ e. Test the performance of the vehicle.

Objective 3

List two benefits of the operator questionnaire.

a. ____

b. ____

Objective 4

Describe two major checkpoints in a visual inspection of the following engine systems.

a. Cooling system

- ____
- ____

b. Electrical system

- ____
- ____

c. Air intake system

- ____
- ____

Objective 5

Describe one major performance checkpoint for the following engine systems.

a. Lubrication system — ______________________________

____

b. Fuel system — ______________________________

____

a. Exhaust system — ______________________________

____

Objective 6

Discuss five performance tests that can be made with the engine on a dynamometer.

a. ______________________________

b. ______________________________

c. ______________________________

d. ______________________________

e. ______________________________

Objective 7

Distinguish among the functions of engine computer fault detection by writing:

- "1" if the statement is about sensing abnormal operation.
- "2" if the statement is about communicating with the driver.
- "3" if the statement is about communicating with the technician.

_____ a. Warning light

_____ b. ECM determines extent of variation

_____ c. Fault code stored in memory

_____ d. ECM detects abnormal input from sensors

_____ e. Snapshot data

Objective 8

Match the methods of engine computer fault code storage with the correct descriptions. Write your answers in the blanks provided.

1. Active code 2. Inactive code 3. Snapshot data

_____ a. "Check Engine" light illuminates while problem exists. Fault code is stored in memory.

_____ b. ECM records engine operating conditions for a short-time before and after the fault occurred. ECM records the time (in engine hours). Fault code is stored in memory.

_____ c. "Check Engine" light comes on and stays on. Fault code is stored in memory.

Written Test

Objective 9

Match methods of engine computer fault code retrieval with the correct descriptions. Write your answers in the blanks provided.

1. "Check Engine" light
2. Hand-held communication tool
3. Personal computer with a translator device

_____ a. Connects to DDL; shows any fault stored in memory; initiates diagnostic sequence for ECM to check all electronic components; allows technician to see sensor output and actuator response

_____ b. Connects to DDL and translator; shows fault codes; shows snapshot parameters on screen; allows technician to reprogram PROM (or EEPROM) with new parameters (on some systems)

_____ c. System is activated; lamp flashes are translated as digits for fault codes; technician can access fault codes with no test equipment

Objective 10

Complete the following statements concerning SAE code identifiers by filling in the blanks with the correct answers.

a. Each fault code uses three, three-digit number groups to describe the ____________________.

b. The first three-digit number group is for the ____________________ identifier, which identifies which microprocessor is broadcasting the code.

c. The second three-digit number group is for the ____________________ identifier, which gives a numerical value (either degrees, volts, or psi) or ____________________ identifier, which identifies the part that is malfunctioning.

d. The third three-digit number group is for the fault mode identifier, which identifies what is wrong with the ____________________; it also indicates whether the problem relates to current flow or voltage.

***Permission to duplicate this test is granted.**

Answers to Written Test

Objective 1

a. 11
b. 8
c. 5
d. 4
e. 13
f. 9
g. 1
h. 12
i. 7
j. 2
k. 10
l. 3

Objective 2

a. 2
b. 1
c. 5
d. 4
e. 3

Objective 3

Any two of the following

a. Provides direct communication between operator and technician
b. Assists technician in troubleshooting, especially when no fault codes are available
c. Eliminates wasted technician time by providing specific information

Objective 4

a. Cooling system—Any two of the following:
  - Level
  - Condition (supplemental coolant additive level)
  - Maintenance history
  - Leaks (radiator/hoses/pump)

b. Electrical system—Any two of the following:
  - Belts
  - Connections (clean and tight/corroded)
  - Wiring harnesses/connectors
  - Battery electrolyte level
  - Charging system

c. Air intake system—Any two of the following:
  - Filter(s)
  - Ducting/hoses
  - Clamps/joints
  - Turbocharger

Objective 5

a. Lubrication system—Any one of the following:
  - Pressure check with shop gauge
  - Temperature check (sump)

b. Fuel system—Any one of the following:
  - Pressure check
  - Flow (amount in a given time)
  - Aeration

c. Exhaust system—Any one of the following:
  - Restriction (back pressure)
  - Turbocharger noise

Answers to Written Test

Objective 6

Any five of the following
a. Engine power output—horsepower or torque
b. Exhaust smoke analysis
c. Fuel consumption
d. Crankcase blow-by
e. Air intake system—restriction or boost pressure
f. Exhaust system—back pressure or temperature
g. Lubrication system—pressure or temperature

Objective 7

a. 2
b. 1
c. 3
d. 1
e. 3

Objective 8

a. 2
b. 3
c. 1

Objective 9

a. 2
b. 3
c. 1

Objective 10

a. Problem
b. Message (MID)
c. Parameter (PID), Subsystem (SID)
d. Sensor signal

Unit 1-D General Engine Diagnosis

Prerequisites:
None

Learning Activities Sheet

Student Name ______________________________

Place a checkmark in the appropriate box as you complete each of the steps below.

☐ 1. **Take** Pretest provided by instructor. After test has been evaluated, follow instructor's recommendations.

☐ 2. **Read** Objective Sheet.

☐ 3. **Study** Information Sheet, Objectives 1 through 3.

☐ 4. **Do** Assignment Sheet 1, "Conduct an Operator Survey for Engine Diagnosis".

☐ 5. **Stop** Have instructor evaluate the completed assignment sheet and if the evaluation is satisfactory, continue to step 6. If the evaluation is not satisfactory, repeat steps 3 and 4.

☐ 6. **Study** Information Sheet, Objectives 4 through 10.

☐ 7. **Do** Assignment Sheet 2, "Interpret SAE Code Identifiers".

☐ 8. **Stop** Have instructor evaluate the completed assignment sheet and if the evaluation is satisfactory, continue to step 9. If the evaluation is not satisfactory, repeat steps 7 and 8.

☐ 9. **Observe** Demonstration of procedures to be used in completing Job Sheet 1.

☐ 10. **Do** Job Sheet 1, "Check Air Intake System for Restrictions".

☐ 11. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 12. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 1 and repeat steps 9 through 11.

☐ 12. **Observe** Demonstration of procedures to be used in completing Job Sheet 2.

☐ 13. **Do** Job Sheet 2, "Check Exhaust Back Pressure".

☐ 14. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 15. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 2 and repeat steps 12 through 14.

☐ 15. **Observe** Demonstration of procedures to be used in completing Job Sheet 3.

☐ 16. **Do** Job Sheet 3, "Check Crankcase Pressure".

☐ 17. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 18. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 3 and repeat steps 15 through 17.

☐ 18. **Observe** Demonstration of procedures to be used in completing Job Sheet 4.

☐ 19. **Do** Job Sheet 4, "Check Oil Pressure".

☐ 20. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 21. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 4 and repeat steps 18 through 20.

☐ 21. **Observe** Demonstration of procedures to be used in completing Job Sheet 5.

☐ 22. **Do** Job Sheet 5, "Load Test an Engine with a Dynamometer".

☐ 23. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 24. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 5 and repeat steps 21 through 23.

☐ 24. **Observe** Demonstration of procedures to be used in completing Job Sheet 6.

☐ 25. **Do** Job Sheet 6, "Locate a Misfiring Cylinder".

☐ 26. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 27. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 6 and repeat steps 24 through 26.

☐ 27. **Observe** Demonstration of procedures to be used in completing Job Sheet 7.

☐ 28. **Do** Job Sheet 7, "Locate an Active Fault Code".

☐ 29. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 30. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 7 and repeat steps 27 through 29.

☐ 30. **Check** With instructor for any additional assignments to be completed.

☐ 31. **Take** Posttest provided by instructor. After test has been evaluated, follow instructor's recommendations.

☐ 32. **Stop** Have instructor evaluate your unit performance. If the evaluation is satisfactory, proceed to next learning activities sheet. If evaluation is not satisfactory, ask instructor for further instructions.

***Permission to duplicate this form is granted.**

Unit Contents

Teacher Page

Teacher Components

Suggested Activities 2D-3
Answers to Assignment Sheets 2D-9
Written Test 2D-11
Answers to Written Test 2D-15
Learning Activities Sheet 2D-17

Student Page

Student Components

Objective Sheet 2D-3
Information Sheet 2D-5

Student Supplements

1—Example of Vehicle Engine Preventive Maintenance Schedule 2D-9
2—Example of Off-Road Equipment Preventive Maintenance Schedule 2D-15
3—Example of Stationary Preventive Maintenance Schedule 2D-17
4—Example of Flowchart Style Maintenance Troubleshooting Chart 2D-23
5—Example of Narrative Style Maintenance Troubleshooting Chart 2D-25

Assignment Sheets

1—Determine Maintenance Needed for Given Situations 2D-27
2—Interpret Maintenance Troubleshooting Charts 2D-31

Job Sheets

1—Inspect Engine Coolant Level and Condition 2D-33
2—Pressure Test Coolant System and Radiator Cap 2D-37
3—Take Oil Sample, and Change Oil and Filter(s) 2D-41
4—Inspect and Test Indicator System Components 2D-45
5—Perform a Daily Preventive Maintenance Check 2D-49
6—Perform a Mileage Preventive Maintenance Check 2D-53
7—Perform an Engine Tune-Up 2D-59

Suggested Activities

Instructional Plan

Preparation

- Read the unit carefully and plan for instruction.
- Review "Teaching Suggestions." Plan for classroom activities.
- Plan your presentation to take advantage of student learning styles and to accommodate special-needs students.
- Prepare classroom. Put up posters and charts and display articles and other references related to this unit.
- Obtain films, videotapes, and other resources to supplement instruction of this unit. See "Resources Used in Developing This Unit" and "Suggested Supplemental Resources" for more information.
- For self-paced instruction, review Learning Activities Sheet. Modify as appropriate to include additional activities and/or resources available in your classroom. Make one copy for each student.

Delivery and Application

Unit Introduction (self-paced instruction)

- Provide student with Learning Activities Sheet and unit of instruction.
- Review unit contents with student.
- Have the student complete the steps in the learning activities sheet.

Unit Introduction (group instruction)

- Provide students with unit of instruction.
- Discuss unit and specific objectives.
- Discuss the information sheet. Implement teaching plan to localize, supplement, and personalize the unit. Reinforce basic academic and workplace skills when applicable.
- Discuss the assignment sheets. Review with students the criteria for evaluation of these activities.

Suggested Activities

- Discuss and demonstrate the job sheets. Make sure all required tools, equipment, and materials are available. Review with students the criteria for evaluation of these activities and the rating scale that will be used to indicate job performance.

Teaching Suggestions

- Invite a local diesel technician to talk to the class about the types of preventive maintenance procedures commonly performed, how much shop time is spent on preventive maintenance, and the most common problems found during basic preventive maintenance checks and inspections. Have the speaker relate personal experiences related to preventive maintenance and tune-ups.
- Show examples of manufacturers' preventive maintenance charts. Demonstrate how to use these charts and where to locate them in manufacturers' service manuals. Also have the students determine how the different manufacturers designate their preventive maintenance intervals (days, hours, mileage, or fuel consumption).
- Take students on a walk-around inspection of a basic vehicle in the shop, and point out engine areas and components that require preventive maintenance as outlined in objective 6.
- The assignment sheets were designed to give students experience in reading and interpreting some examples of maintenance schedules and troubleshooting charts given in the student supplements (1-5). You may also want to develop additional assignments using reference materials in your shop/classroom.
- Demonstrate any electronic databases or on-line services available in your shop for preventative maintenance, troubleshooting, and tune-ups. If unavailable, you might want to take students on a field trip to a local diesel service center using these services so students can see the new technology available.

Evaluation

- Make copies of the written test. Add or modify test items as needed. The written test serves as both a pretest and posttest to assist in measuring each student's competency gains.
- Give and evaluate pretest. Modify lesson plan to include additional instruction for those areas where students were deficient.
- Evaluate the assignment sheets. Rate the student using the criteria listed on each assignment sheet. See Answers to Assignment Sheets for correct answers where applicable. If the student's performance is unacceptable, have the student review the appropriate materials and complete the assignment again.

Suggested Activities

- Evaluate the job sheets. When the student is ready to perform a specific task, obtain a copy of the job sheet which may be found in the student edition. Then observe the student performing the procedure.

  Process evaluation—Place a mark in the box to the left of each designated checkpoint if the student has satisfactorily completed the process step(s) for each checkpoint area. If the student is unable to complete the procedure correctly, have the student review the materials and try again.

  Product evaluation—Once the student has satisfactorily completed the procedure, rate the student product (outcome) using the criteria that are provided as part of the job sheet. If the student's product is unacceptable, have the student review the materials and submit another product for evaluation.

  Two sample performance evaluation keys have been provided below. Many other keys are available. Select one rating (grading scale) that best fits your program needs.

  Sample A

  4—**Skilled**—Can perform job with no additional training.
  3—**Moderately skilled**—Has performed job during training program; limited additional training may be required.
  2—**Limited skill**—Has performed job during training program; additional training is required to develop skill.
  1—**Unskilled**—Is familiar with process, but is unable to perform job.
  0—**No exposure**—No information or practice provided during training program.

  Sample B

  Yes—Can perform job with no additional training.
  No—Is unable to perform job satisfactorily.

- Give and evaluate the posttest.

- Meet individually with students to evaluate their progress through this unit of instruction and indicate to them possible areas of improvement.

- Reteach and retest as required.

Resources Used in Developing This Unit

Print Media

- Clark, Elton, et al. *Diesel Fundamentals.* Stillwater, OK: Mid-America Vocational Curriculum Consortium, Inc., 1988.

- Dagel, John F. *Diesel Engine and Fuel System Repair*, 3rd ed. Upper Saddle River, NJ: Prentice Hall, 1994.

- Espenschied, Roland F. *Diesel Engines.* Athens, GA: American Association for Vocational Instructional Materials, 1990.
- *Fundamentals of Service: Engines,* 7th ed. Moline, IL: Deere and Company, 1991.
- *Rebuild Manual, Cummins Diesel 10 Litre Engines.* Columbia, IN: Cummins Engine Co., 1984.
- *Series 60 Service Manual.* Detroit, MI: Detroit Diesel Corp., 1995.
- *Service Manual, 3176B Diesel Truck Engine.* Peoria, IL: Caterpillar, Inc., 1995.
- *Service Manual, D11N Tractor.* Peoria, IL: Caterpillar, Inc., 1991.

Note: Engine manuals can be ordered through the local dealerships.

Suggested Supplemental Resources

Print Media

- *ASE Test Prep Series*—Medium/Heavy Duty Truck, 2nd ed. (Diesel Engines). Albany, NY: Delmar Publishers, 2002.

  Also available in CD ROM format
- Bennett, Sean. *Medium/Heavy Duty Truck Engines, Fuel and Computerized Management Systems.* Albany, NY: Delmar Publishers, 1999.
- Bennett, Sean. *Today's Technician: Medium/Heavy Duty Truck Diesel Engines.* Albany, NY: Delmar Publishers, 2001.
- *Maintenance and Lubrication Service Manual.* (3-101) Available from:

  Mack Trucks, Inc.
  2100 Mack Boulevard
  P.O. Box M
  Allentown, PA 18195-5000
  610-439-3011
- *Preventive Maintenance Inspection (PMI) Guidelines: Class 7 and 8 Diesel-Powered Tractors With Air Brakes,* ©1995 (#T0450). Booklet available from:

  The Maintenance Council
  American Trucking Association
  2200 Mill Road
  Alexandria, VA 22314
  707-838-1763 or fax 703-684-4328

Electronic Media

- *N 14/L 10 Command CELECT Overhead Adjustment.* (3387746). Available VHS videotape.
- *N 14/L 10 Command STC Overhead Adjustment.* (3387756). Available VHS videotape.
- *N 14/L 10 STC Overhead Adjustment–Outer Base Circle (OBC) Method.* (3387796). Available as VHS videotape:

  The above are available from your local Cummins Engine Company dealer/distributor or call:

  Cummins Engine Company Customer Relations
  800-345-5654 or 502-453-8549 or for more information call 1-800-DIESELS

- *Preventive Maintenance Unit One: Fuel System*, VHS, 26 minutes. Discusses ongoing care of diesel fuel systems. 1992.
- *Preventive Maintenance Unit Two: Air System*, VHS, 21 minutes. Discusses air cleaners, breathers, compressors, and turbochargers. 1992.
- *Preventive Maintenance Unit Three: Cooling System*, VHS, 23 minutes. Discusses heat dissipation, coolant levels, fans, and filters. 1992.
- *Preventive Maintenance Unit Four: Lubricating System*, VHS, 19 minutes. Shows checking for leaks, oil changes, filter changes, and types of filters. 1992.
- *Preventive Maintenance Unit Five: Electrical System*, VHS, 23 minutes. Shows battery care, battery charging, how to test battery cables, pinion clearance, and amperage draw check.

  The above are available from:

  NIMCO
  102 Hwy. 81 North
  P.O. Box 9
  Calhoun, KY 42327-0009
  Phone: 800-962-6662 or Fax: 502-273-5844
  http://www.nimcoinc.com

Suggested Activities

- *Preventive Maintenance Programs: Engines.* #DGVHU72049. VHS, 60 minutes
- *Fundamentals of Service: Fuels, Lubricants, Coolants.* #FOS5807B-152. Textbook
- *Fundamentals of Service: Fuels, Lubricants, Coolants.* #FOS5807S-152. Slide set

For information concerning application or availability of the three items listed above, call or write:

Deere and Company
Distribution Service Center
P.O. Box 186
Moline, IL 61266-1086
319-388-4546

Answers to Assignment Sheets

Assignment Sheet 1

Determine Maintenance Needed for Given Situations

Note: For each situation, the student should list specific tasks, not general categories.

Situation 1

Student should list all tasks stated under 13.3.11 150,000 Mile Interval Maintenance (Detroit Diesel Series 60 Service Manual)

1. Treat fuel tank with biocide
2. Lubricate tach drive
3. Inspect/Adjust drive belts
4. Service air compressor air intake and tighten mounting bolts
5. Check exhaust manifold bolts and connections
6. Steam clean the engine
7. Inspect/clean the outside of the radiator core
8. Inspect/clean battery terminals and connections for corrosion and tightness
9. Change oil and lube filters
10. Replace fuel filters
11. Inspect the water pump for leakage and replace the coolant filter

Situation 2

Student should list all tasks stated under 250 hour service (Caterpillar D11N Lubrication and Maintenance Chart)

1. Change crankcase oil and filters
2. Inspect/adjust alternator and air conditioner belts
3. Test/adjust brakes
4. Adjust tracks (if needed)
5. Add coolant conditioner
6. Lubricate fittings on equalizer bar end pins
7. Inspect final drive oil level

Situation 3

Student should list all tasks stated under 13.4.9 1,200 hour maintenance (Detroit Diesel Series 60 Service Manual)

1. Treat fuel tank with biocide
2. Lubricate tach drive
3. Service air compressor air intake and tighten mounting bolts
4. Check intake system ducting and hoses for punctures, deterioration, or leakage

5. Check exhaust manifold bolts and connections
6. Steam clean the engine
7. Inspect/clean the outside of the radiator core
8. Start engine and log oil pressure
9. Inspect/clean battery terminals and connections for corrosion and tightness; check wiring for frayed insulation
10. Check engine mounting bolts and pads
11. Check and record crankcase pressure
12. Inspect thermostats and seals
13. Remove and clean crankcase breather
14. Change oil and lube filters
15. Replace fuel filters
16. Inspect the water pump for leakage and replace the coolant filter

Assignment Sheet 2

Interpret Maintenance Troubleshooting Charts

Part I

1. a. Remove oil pressure relief valve
   b. Disassemble oil pressure relief valve and gasket
   c. Clean

2. Clean with emery cloth or replace

3. a. Relief valve binds
   b. Scored valve or valve body

4. After

Part II

1. a. Batteries
   b. Starter circuit problem (in machine wiring)
   c. Starter solenoid
   d. Starter motor
   e. Starter ring gear
   f. Transmission or power take-off problem
   g. Hydraulic cylinder lock
   h. Internal engine problem

2. SEH 9249

3. 4C4911 Battery Load Tester

4. Remove individual nozzles

5. Disassemble engine

Written Test

Name ______________________________

Date ______________________ Score __________

Objective 1

Match terms related to preventive maintenance with their definitions. Write the corresponding numbers on the blanks provided.

1. Biocide
2. Check
3. Hubmeter
4. Interval
5. Log
6. OTR
7. Preventive maintenance
8. Schedule
9. Severe service
10. Symptom
11. Tune-up

_____ a. Collection of written information concerning the operation, maintenance, and repair records for a given vehicle, engine, or piece of equipment; usually kept in a notebook or binder

_____ b. Plan that indicates the time and sequence of each operation in a procedure

_____ c. Systematic and periodic inspection and servicing of vehicles and their components

_____ d. Checks and adjustment of engine components back to manufacturer's specifications

_____ e. Use of a vehicle or other equipment under conditions that are harsh, extreme, or require great effort

_____ f. Chemical that kills microorganisms such as bacteria and fungi that may be found in fuel tanks

_____ g. Span of time between events (such as oil changes, fuel line inspections, etc.)

_____ h. Indication of mechanical or electrical trouble

Written Test

Objective 2

Distinguish between purposes of preventive maintenance and tune-up by placing a "PM" next to the purposes of preventive maintenance and a "T" next to the purposes of tune-up.

_____ a. To prevent costly failures and breakdowns

_____ b. To correct for wear

_____ c. To detect and correct problems

_____ d. To ensure optimum component life

_____ e. To obtain optimum engine performance

Objective 3

Complete statements on locating preventive maintenance charts and information by filling in the blanks with the correct answers.

a. May be located in the manufacturers' operation and maintenance manuals or included as a separate section of the _____________________ _____________________

b. May also be available as _____________________ to some engine manufacturers' manuals

Objective 4

List two ways of designating preventive maintenance intervals.

a. _____________________

b. _____________________

Objective 5

Select from the following list conditions that require severe service maintenance schedules by placing an "X" in front of the correct conditions.

_____ a. Operation at varying throttle settings and load levels

_____ b. Frequent hot shutdowns

_____ c. Off-highway operation

_____ d. Operation with gross vehicle weights under 80,000 pounds

_____ e. Low altitude operation

_____ f. Sub-zero operation

_____ g. Extended operation at low idle

Objective 6

Describe three engine areas requiring preventive maintenance and briefly mention the basic components that will be checked/serviced.

a. ____

____

b. ____

____

c. ____

____

Objective 7

Complete statements concerning preventive maintenance for diesel fuel systems by filling in the blanks with the correct answers.

a. Fill the ____________________ at the end of each day to minimize condensation.

b. Drain ____________________ weekly.

c. Add ____________________ if needed.

Objective 8

Arrange in order the following steps for a diesel engine tune-up by placing the correct sequence numbers (1-3) in the appropriate blanks.

_____ a. Adjust injectors.

_____ b. Adjust valves.

_____ c. Adjust slave piston lash (if required).

***Permission to duplicate this test is granted.**

Answers to Written Test

Objective 1

a. 5
b. 8
c. 7
d. 11
e. 9
f. 1
g. 4
h. 10

Objective 2

a. PM
b. T
c. PM
d. PM
e. T

Objective 3

a. Engine manufacturers' service manual
b. Supplements

Objective 4

Any two of the following:

a. By time or duty cycle
b. By service hours
c. By mileage
d. By fuel consumption

Objective 5

b, c, f, g

Objective 6

Any three of the following:

a. Air intake and exhaust system
  - Ducting
  - Intercooler
  - Turbocharger/supercharger

b. Cooling system
  - Coolant condition and level
  - Coolant filters
  - Radiator
  - Belts and hoses
  - Fan hub and clutch
  - Water pump
  - Thermostat
  - Heater

c. Electrical system (engine accessory)
  - Battery
  - Alternator
  - Starter
  - Cables/wiring harness

Answers to Written Test

d. Fuel system
  - Tanks
  - Lines
  - Filters
  - Pump
  - Injectors/injector pump
  - Throttle linkage

e. Lubricating system
  - Oil condition and level
  - Oil filters/screens
  - Pump (system pressure)

f. Engine fasteners
  - Mounting bolts
  - Housings
  - Hold-Downs

Objective 7

a. Fuel tanks
b. Water/sediment
c. Biocide

Objective 8

a. 2
b. 1
c. 3

470

Prerequisites:
None

Learning Activities Sheet

Student Name ______________________________

Place a checkmark in the appropriate box as you complete each of the steps below.

☐ 1. **Take** Pretest provided by instructor. After test has been evaluated, follow instructor's recommendations.

☐ 2. **Read** Objective Sheet.

☐ 3. **Study** Information Sheet, Objectives 1 through 6.

☐ 4. **Do** Assignment Sheet 1, "Determine Maintenance Needed for Given Situations".

☐ 5. **Stop** Have instructor evaluate the completed assignment sheet and if the evaluation is satisfactory, continue to step 6. If the evaluation is not satisfactory, repeat steps 3 and 4.

☐ 6. **Do** Assignment Sheet 2, "Interpret Maintenance Troubleshooting Charts".

☐ 7. **Stop** Have instructor evaluate the completed assignment sheet and if the evaluation is satisfactory, continue to step 8. If the evaluation is not satisfactory, repeat steps 3 and 6.

Optional

☐ 8. **View** Videotape entitled: "Preventive Maintenance Unit 3: Cooling System".

☐ 9. **Observe** Demonstration of procedures to be used in completing Job Sheet 1.

☐ 10. **Do** Job Sheet 1, "Inspect Engine Coolant Level and Condition".

Learning Activities Sheet

☐ 11. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 12. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 1 and repeat steps 9 through 11.

☐ 12. **Observe** Demonstration of procedures to be used in completing Job Sheet 2.

☐ 13. **Do** Job Sheet 2, "Pressure Test Coolant System and Radiator Cap".

☐ 14. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 15. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 2 and repeat steps 12 through 14.

Optional

☐ 15. **View** Videotape entitled: "Preventive Maintenance Unit 4: Lubricating System".

☐ 16. **Observe** Demonstration of procedures to be used in completing Job Sheet 3.

☐ 17. **Do** Job Sheet 3, "Take Oil Sample, and Change Oil and Filter(s)".

☐ 18. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 19. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 3 and repeat steps 16 through 18.

Optional

☐ 19. **View** Videotape entitled: "Preventive Maintenance Unit 5: Electrical System".

☐ 20. **Observe** Demonstration of procedures to be used in completing Job Sheet 4.

☐ 21. **Do** Job Sheet 4, "Inspect and Test Indicator System Components".

☐ 22. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 23. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 4 and repeat steps 20 through 22.

Optional

☐ 23. **View** Videotapes entitled: "Preventive Maintenance Unit 1: Fuel System"and "Preventive Maintenance Unit 2: Air System".

☐ 24. **Observe** Demonstration of procedures to be used in completing Job Sheet 5.

☐ 25. **Do** Job Sheet 5, "Perform a Daily Preventive Maintenance Check".

☐ 26. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 27. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 5 and repeat steps 24 through 26.

☐ 27. **Study** Information Sheet, Objective 7.

☐ 28. **Observe** Demonstration of procedures to be used in completing Job Sheet 6.

☐ 29. **Do** Job Sheet 6, "Perform a Mileage Preventive Maintenance Check".

☐ 30. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 31. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 6 and repeat steps 28 through 30.

☐ 31. **Study** Information Sheet, Objective 8.

☐ 32. **Observe** Demonstration of procedures to be used in completing Job Sheet 7.

☐ 33. **Do** Job Sheet 7, "Perform an Engine Tune-Up".

☐ 34. **Stop** Have instructor evaluate your performance and if the evaluation is satisfactory, continue to step 35. If the evaluation is not satisfactory, study the procedure outlined in Job Sheet 7 and repeat steps 32 through 34.

☐ 35. **Check** With instructor for any additional assignments to be completed.

Learning Activities Sheet

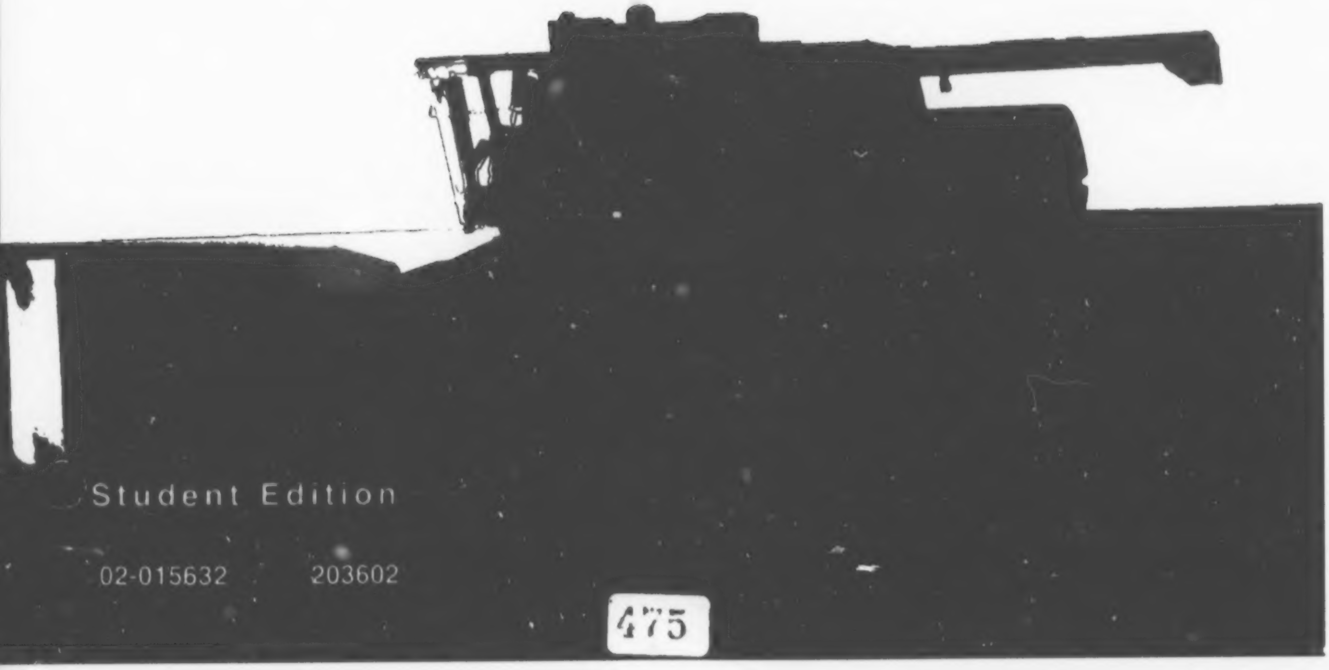
☐ 36. **Take** Posttest provided by instructor. After test has been evaluated, follow instructor's recommendations.

☐ 37. **Stop** Have instructor evaluate your unit performance. If the evaluation is satisfactory, proceed to next learning activities sheet. If evaluation is not satisfactory, ask instructor for further instructions.

***Permission to duplicate this form is granted.**

Diesel Technology
Engines

Second Edition



Student Edition

02-015632 203602

475

Diesel Technology: Engines

Second Edition

Student Edition

Written by

Dave Barbieri
Roger Miller
Mary Kellum

Project coordinated by

Mary Kellum
Instructional Development Specialist

Developed by

Multistate Academic and Vocational Curriculum Consortium, Inc.
(MAVCC)
1500 West Seventh Avenue
Stillwater, Oklahoma 74074-4364

©2002

The Multistate Academic and Vocational Curriculum Consortium does not discriminate on the basis of race, creed, color, national origin, sex, age, religion, veteran status, or qualified handicap.

02-015632

203602

Table of Contents

Units of Instruction

Section A: Introduction to Engine Principles and Procedures

Unit 1–A: Engine Operating Principles

Unit 2–A: Disassembly Procedures and Analysis

Section B: Engine Systems and Components

Unit 1–B: Lubrication Systems

Unit 2–B: Cooling Systems

Unit 3–B: Cylinder Blocks and Liners

Unit 4–B: Crankshafts and Bearings

Unit 5–B: Pistons and Connecting Rods

Unit 6–B: Camshafts, Trains, and Timing

Unit 7–B: Cylinder Head Assemblies

Unit 8–B: Air Induction and Exhaust

Unit 9–B: Engine Brakes and Retarders

Section C: Fuel Systems

Unit 1–C: Basic Fuel Systems and Components

Unit 2–C: Mechanical Fuel Injection Diagnosis and Repair

Unit 3–C: Electronic Fuel Injection Diagnosis and Repair

Unit 4–C: Emissions

Section D: Engine Diagnosis and Maintenance

Unit 1–D: General Engine Diagnosis

Unit 2–D: Preventive Maintenance and Tune-Up

Unit 1-A

Engine Operating Principles

Unit Contents

Student Components

Student Page

Objective Sheet 1A-3

Information Sheet 1A-5

Assignment Sheets

1—Identify Companion Cylinders 1A-17
2—Locate and Record Engine Specifications 1A-19
3—Identify Valve and Piston Position During Each Stroke 1A-23

Job Sheets

1—Locate TDC for #1 Piston 1A-25
2—Measure Bore and Stroke and Compute Engine Displacement . 1A-29

Objective Sheet

Unit Objective

After completing this unit, the student should be able to describe the operation of a diesel engine, identify engine components, and describe their functions. The student should also be able to identify companion cylinders and valve and piston positions during each stroke, as well as locate TDC compression for #1 piston, measure bore and stroke, and compute engine displacement. The student should demonstrate these competencies by completing the assignment sheets and job sheets and by scoring a minimum of 85 percent on the written test.

Specific Objectives

After completing this unit, the student should be able to:

1. Match terms related to engine operating principles with their definitions.
2. Match basic engine systems with their functions.
3. Identify basic engine components on two-stroke and four-stroke diesel engines.
4. Match basic internal engine components with their functions.
5. Distinguish between gasoline and diesel engines.
6. Complete statements concerning strokes on a four-stroke diesel engine.
7. Distinguish between strokes on a two-stroke diesel engine.
8. Distinguish between operating characteristics of two-stroke and four-stroke diesel engines.
9. Identify companion cylinders. (Assignment Sheet 1)
10. Locate and record engine specifications. (Assignment Sheet 2)
11. Identify valve and piston position during each stroke. (Assignment Sheet 3)
12. Locate TDC compression for #1 piston. (Job Sheet 1)
13. Measure bore and stroke and compute engine displacement. (Job Sheet 2)

Information Sheet

Objective 1

Terms and definitions

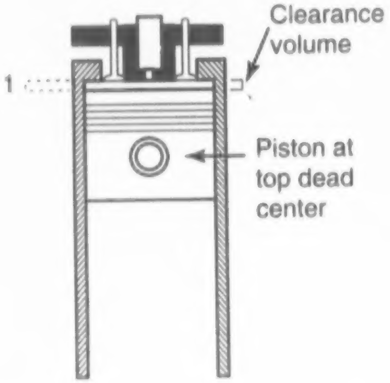
a. **Accessory**—Component that is not always essential to the operation of the engine

Example: Air compressor

b. **Bottom Dead Center (BDC)**—Location of the piston at its lowest point of travel

c. **Clearance volume**—Total space between the cylinder head and the piston at top dead center

Figure 1



d. **Combustion**—Burning the air/fuel mixture to produce heat

e. **Companion cylinders**—Cylinders whose pistons reach TDC or BDC together

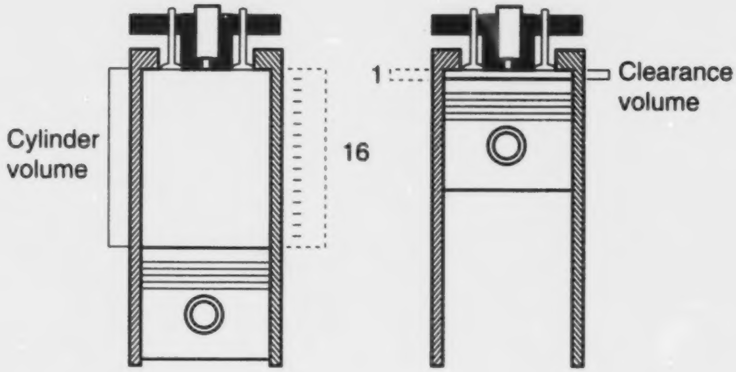
f. **Component**—Member of a system; group of connected parts and/or assemblies often contained within a housing and designed to perform a specific but limited function within a system

g. **Compression**—Reducing the volume of the trapped air in the cylinder by pushing the piston upward

h. **Compression ratio**—Ratio of cylinder volume to clearance volume; a measure of how much the air has been compressed

Example: If the cylinder volume is 80 in^3 and clearance volume is 5 in^3, then the compression ratio is 80:5 or 16:1.

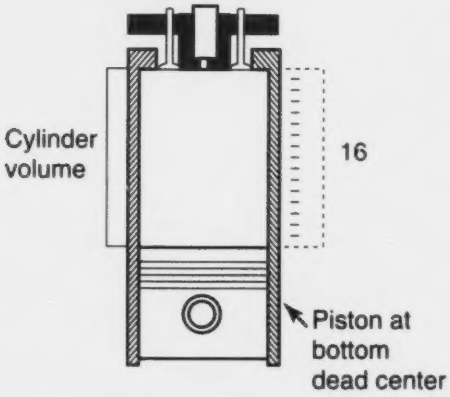
Figure 2


Cylinder volume
16
1
Clearance volume

i. **Cycle**—Series of events that repeat themselves in a regular sequence

j. **Cylinder volume**—Total space between the cylinder head and the piston at bottom dead center

Figure 3


Cylinder volume
16
Piston at bottom dead center

k. **Displacement**—To move physically out of position or to take the place of

l. **Engine speed**—Crankshaft revolutions per minute (RPM)

m. **Firing order**—Sequence in which the cylinders, beginning with number 1 cylinder, deliver their power stroke

n. **Horsepower**—Measurement of an engine's power

o. **Integral**—Formed as a unit with another part

p. **Overspeed**—When an engine exceeds its governed maximum no-load RPM's

q. **Power control**—Controlling engine power by varying the amount of fuel injected into the combustion chamber

r. **Precombustion chamber**—Small cavity in the cylinder head of some diesel engines where fuel ignition and combustion first occur

s. **Pump**—Device that transfers fluids or gases using suction or pressure or both

t. **Reciprocating motion**—Movement up-and-down

Example: Pistons use reciprocating motion.

u. **Rotary motion**—Movement in a circular manner

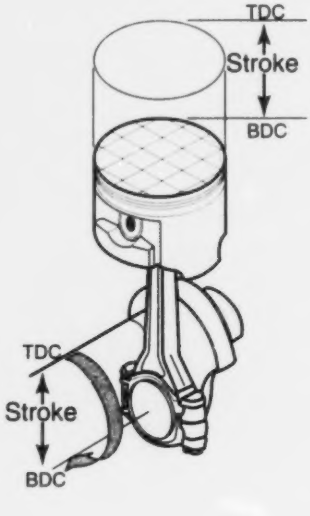
Examples: Crankshafts, fan blades, and wheels use rotary motion.

v. **Scavenging**—Using the intake of fresh air to clear exhaust gases from the cylinder

w. **Stroke**—Distance the piston travels from TDC to BDC, or from BDC to TDC

Note: Depending on the design, diesel engines require either two strokes or four strokes to complete a cycle.

Figure 4



x. **System**—Group of interconnected components or assemblies arranged in such a way that their separate functions work together to accomplish a broader function

y. **Temperature**—Measure of heat intensity

z. **Thermostat**—Automatic device for regulating temperature

aa. **Top Dead Center (TDC)**—Location of the piston at its highest point of travel

bb. **Torque**—Measurement of twisting force

cc. **Valve**—Device for sealing the intake and/or exhaust ports in a cylinder head

dd. **Valve overlap**—Period of time, measured in crankshaft degrees, that both the intake and exhaust valves are open; allows scavenging to occur

Objective 2

Basic engine systems and their functions

a. **Lubrication system**

- Reduces friction by providing lubrication around and between moving parts or contact points within the engine
- Helps transfer heat to cool the engine
- Cleans engine by removing contaminants

b. **Cooling system**—Circulates either air only or air and liquid to transfer heat of combustion and friction away from engine to prevent engine damage

c. **Air intake and exhaust system(s)**—Provides cleaned, pressurized, and cooled air to the engine and then directs exhaust gases to accessory equipment and atmosphere

d. **Fuel system**—Provides fuel storage and delivers fuel to engine using mechanical and/or electronic components

e. **Electrical systems**

- Starting system—Controls and powers electric motor used to start the engine
- Charging system—Produces, controls, and monitors electrical current needed while vehicle is running; also recharges the storage batteries

f. **Electronic-control system**—Electronically monitors and adjusts the operation of various systems (especially fuel) and provides driver and service technician with information about those systems

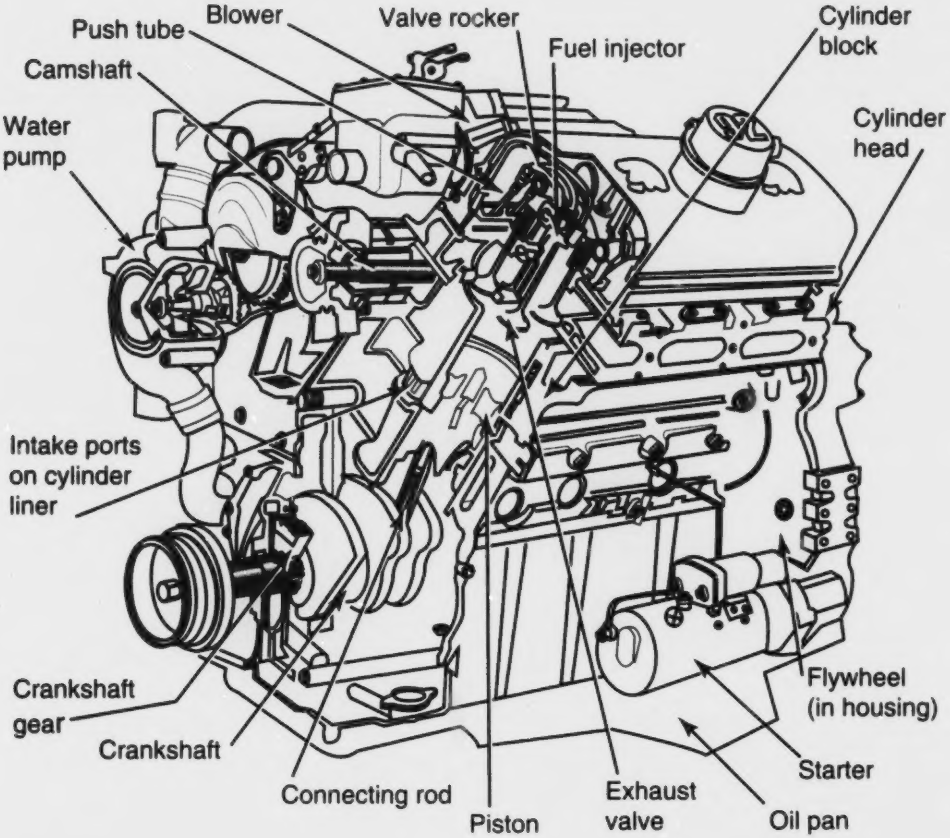
g. **Engine braking system**—Uses the engine's power to help slow the vehicle

Objective 3

Basic diesel engine components

a. Two-stroke diesel engine

Figure 5

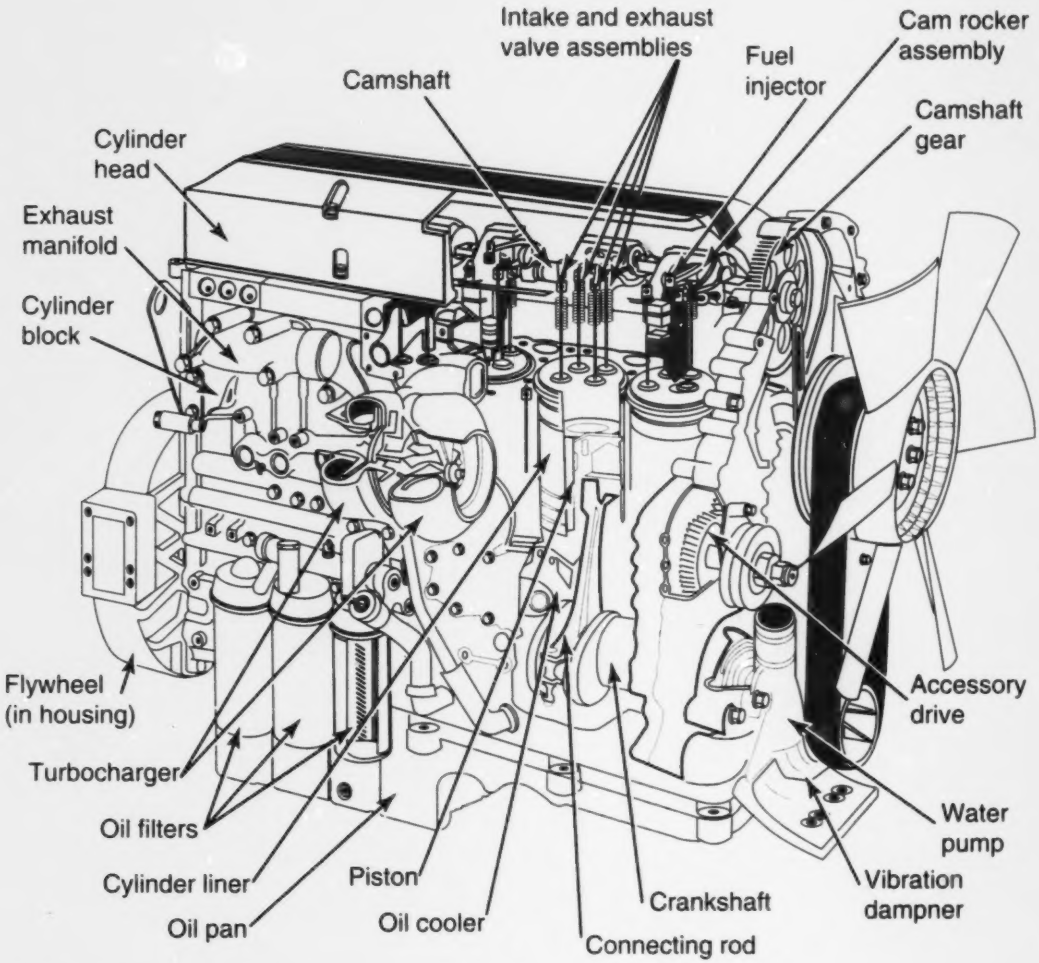

Blower
Push tube
Valve rocker
Cylinder block
Fuel injector
Camshaft
Cylinder head
Water pump
Intake ports on cylinder liner
Crankshaft gear
Crankshaft
Connecting rod
Piston
Exhaust valve
Flywheel (in housing)
Starter
Oil pan

Courtesy of Detroit Diesel Corporation

434

b. Four-stroke diesel engine

Figure 6


Intake and exhaust valve assemblies
Cam rocker assembly
Fuel injector
Camshaft
Camshaft gear
Cylinder head
Exhaust manifold
Cylinder block
Flywheel (in housing)
Turbocharger
Oil filters
Cylinder liner
Oil pan
Piston
Oil cooler
Connecting rod
Crankshaft
Accessory drive
Water pump
Vibration dampner

Courtesy of Detroit Diesel Corporation

465

Objective 4

Basic internal engine components and their functions

a. **Camshaft**—Shaft with eccentric lobes that controls valves, and in some designs, also controls the injectors; driven by chains, belts, or gears

b. **Camshaft gear**—Attached to the camshaft and driven by the crankshaft gear; synchronizes valve operation to crankshaft and piston movement

c. **Connecting rod**—Connects the piston to the crankshaft and transmits the reciprocating motion to the crankshaft

d. **Coolant passage**—Hollow space in either the cylinder block or cylinder head through which coolant circulates

e. **Crankshaft**—Main shaft in the engine powertrain which, turned by the connecting rods, converts the reciprocating motion of the pistons into rotary motion

Note: Offset portions of the crankshaft, known as "throws," form mounting points for the lower end of the connecting rods.

f. **Crankshaft gear**—Drives the camshaft gear or idler gear

g. **Cylinder**—Machined hole in the cylinder block that contains the piston

h. **Cylinder block**—Iron or aluminum alloy casting which houses the cylinders, water and lubrication passages, crankshaft, and in some designs, the camshaft

i. **Cylinder head**—Machined casing bolted to the top of the cylinder block, sealing the top of the cylinder; contains coolant passages, injectors, valves, and in some designs, the camshaft

j. **Exhaust valve**—Opens a port in the cylinder head to allow the spent exhaust gases to be forced from the cylinder

k. **Flywheel**—Attaches to the end of the crankshaft; stores momentum, smoothes out firing pulses, carries the crankshaft around to the next firing pulse, and provides a starter engagement point

l. **Intake valve**—Opens a port in the cylinder head to allow the fresh air charge to be drawn into the cylinder

m. **Oil cooler**—Heat exchanger that cools and regulates the oil temperature

n. **Oil pan**—Reservoir for the engine oil

o. **Oil pump**—Pressurizes oil to circulate it to rotating and reciprocating parts

p. **Piston**—Converts heat energy into reciprocating motion

q. **Push rod or push tube**—Steel rod or tube that transfers reciprocating motion from the valve lifter to the rocker arm

r. **Rocker arm**—Transfers motion from the push rod to the valve

s. **Valve lifter**—Rides on the cam lobe, converting the cam's rotary motion into reciprocating motion; also known as a cam follower

t. **Vibration damper**—Specially designed multi-piece device that mounts to the front of the crankshaft to reduce torsional vibration and prevent crankshaft breakage; also known as a harmonic balancer

Objective 5

Characteristics of gasoline and diesel engines

Characteristics	Diesel Engines	Gasoline Engines
Fuel ignition	Compression ignition—High temperature and high pressure cause fuel to ignite	Electric spark ignition—Spark from spark plug ignites fuel
Intake air	Fresh air is taken directly into the combustion chamber	Fresh air is mixed with fuel first, then brought into the combustion chamber
Fuel delivery system	Fuel is injected directly into the combustion chamber or precombustion chamber	Fuel is mixed with the air charge by carburetion or by fuel injection; the air/fuel mix is then sent through the intake port and into the combustion chamber
Fuel	Burns lower grade fuel oil	Burns highly refined gasoline
Compression	High compression ratio (16-22:1) High pressure (400-600 psi)	Low compression ratio (7-11:1) Lower pressure (100-160 psi)
Construction	Heavy cast iron and forged steel construction	Much lighter construction with extensive use of aluminum and aluminum alloys

Note: Diesel engine components are much heavier and stronger in order to withstand the extremely high levels of heat and pressure that are generated inside the engine.

Objective 6

Four-stroke cycle

a. **First stroke: Intake**

- The intake valve opens.
- Just after the piston reaches TDC, the exhaust valve closes completely.
- Piston moves down, from TDC to BDC, pulling fresh air into the cylinder.

b. **Second stroke: Compression**

- Just after the piston reaches BDC, the intake valve closes completely. Both valves are now closed.
- Piston moves up, from BDC to TDC, compressing the air charge. As the air charge is compressed, its temperature rises to over 1,000°F.
- Just before the piston reaches TDC, fuel injection begins.

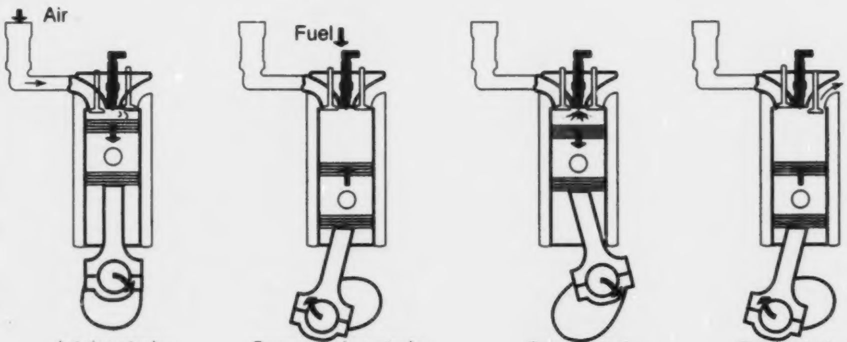
c. **Third stroke: Power**

- Injected fuel mixes with the superheated air and immediately begins to burn.
- The burning fuel/air mixture produces hot gases. The rapidly-expanding gases force the piston down, from TDC to BDC.
- Just before the piston reaches BDC, the exhaust valve starts to open.

d. **Fourth stroke: Exhaust**

- The piston moves up, pushing out the spent gases through the exhaust valve.
- Just before the piston reaches TDC, the intake valve begins to open.

Figure 7—Four-stroke cycle



Intake stroke Compression stroke Power stroke Exhaust stroke

Objective 7

Two-stroke cycle

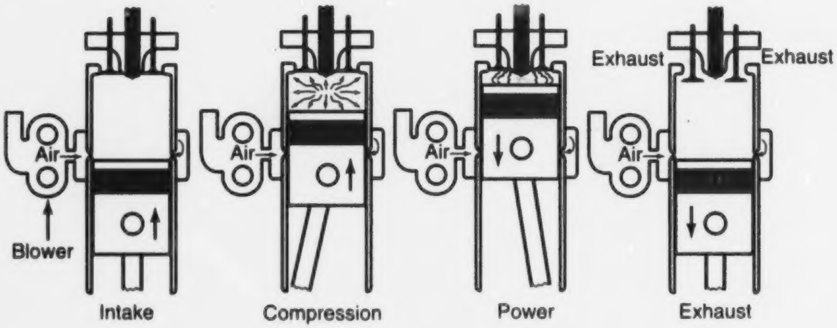
a. **Upstroke: Intake/Compression**

- The piston moves up, from BDC to TDC.
- As the piston moves up the cylinder, the exhaust valves close; cylinder scavenging stops, and cylinder filling begins.
- The rising piston covers the intake ports, cylinder filling stops, and the piston now compresses the air charge.
- As the air charge is compressed, its temperature rises to over 1,000°F.
- Just before the piston reaches TDC, fuel injection begins.

b. **Downstroke: Power/Exhaust**

- Injected fuel mixes with the superheated air and immediately begins to burn.
- The burning fuel/air mixture produces hot gases, and rapidly-expanding gases force the piston down, from TDC to BDC.
- Before the piston reaches the intake ports, the exhaust valves open.
- Hot exhaust gases begin to pour out of the cylinder.
- The piston continues to BDC, uncovering the intake ports.
- Compressed fresh air is forced through the intake ports into the cylinder, pushing the remaining burnt gases out the still-open exhaust valves.

Figure 8—Two-stroke cycle



Objective 8

Characteristics of two-stroke and four-stroke diesel engines

a. **Two-stroke diesel engine**

- Produces a power stroke every crankshaft revolution
- Typically uses a mechanically driven supercharger (blower) for scavenging and cylinder charging
- Creates greater engine heat load than a four-stroke design since the engine fires twice as often
- Has smoother operation since power strokes occur at shorter intervals

b. **Four-stroke diesel engine**

- Produces a power stroke every two crankshaft revolutions
- Does not typically use an engine-driven blower to charge the cylinder
- Is more fuel-efficient due to improved valve timing and more effective scavenging of the exhaust gases

Objective 9

Assignment Sheet 1—Identify Companion Cylinders

Name ______________________ Overall Rating __________

Date ______________________

Evaluation Criterion	Rating
• Companion cylinders correctly identified	______

Basic Skills

Reading Critical Thinking

Introduction

Four-stroke diesel engine crankshafts are designed so that two pistons move up and down at the same time. These pairs are called "companion cylinders," and the crankshaft throws for these two cylinders are called "matched throws." Although the pistons in companion cylinders move in the same direction at the same time, they do not fire at the same time. They are timed 180° out-of-phase—one piston moves up on the compression stroke; its companion moves up on the exhaust stroke.

Directions

Use the following steps and the example to identify the companion cylinders listed as problems.

a. Write out the firing order.

Example: 1-5-3-6-2-4

b. Draw a line through the middle of the firing order, dividing it in half. (Note: 6 cylinders would divide into 2 groups of 3; 8 cylinders into 4 and 4, etc.)

Example: 153/624

c. Write the first set of numbers directly above the second set.

Example: $\underline{1\ 5\ 3}$
6 2 4

d. The vertical pairs that you see are companion cylinders or "matched throws."

Example: Companion cylinders are 1 & 6, 5 & 2, and 3 & 4.

Assignment Sheet 1

Problems: Show your work.

1. Firing order: 1-6-4-7-2-5-3-8

   Companion cylinders: ______________________________

2. Firing order: 1-5-2-6-3-4

   Companion cylinders: ______________________________

3. Firing order: 1-3-5-4-6-8-7-2

   Companion cylinders: ______________________________

Objective 10

Assignment Sheet 2—Locate and Record Engine Specifications

Name ____________________ Overall Rating __________

Date ____________________

Evaluation Criteria	**Rating**
• Correct manual and relevant repair section chosen	______
• Engine specifications correctly recorded	______

Basic Skills

Reading Writing Critical Thinking

Directions

Using the appropriate engine service manual, locate the following information related to engine specifications.

1. General Engine Information

   a. Engine make ____________________

   b. Engine model ____________________

   c. Engine serial number ____________________

   d. Number of cylinders and arrangement ____________________

   e. Displacement: cubic inches __________ liters __________

   f. Two-stroke or four-stroke cycle? ____________________

   g. Advertised horsepower __________ at __________ rpm

   h. Type of fuel system ____________________

   i. Cylinder sleeve type: wet or dry? ____________________

   j. Number of valves per cylinder: Intake ________ Exhaust ________

   k. Oil pump location ____________________

   l. Oil cooler location: ____________________

   m. Location of crankcase breather ____________________

Assignment Sheet 2

n. Crankcase capacity __________ qts

o. Water pump location ______________________________

p. Water pump weep hole ______________________________

q. Thermostat location ______________________________

r. Water manifold location ______________________________

s. Location of all coolant drain plugs.

   1. ______________________________
   2. ______________________________
   3. ______________________________
   4. ______________________________
   5. ______________________________
   6. ______________________________

t. Total number of coolant drain plugs ____________________

u. Vibration damper type: viscous or bonded? ____________________

v. Turbocharger location ______________________________

w. Supercharger location ______________________________

x. Alftercooler location ______________________________

y. Fuel transfer pump location ______________________________

2. Starter specifications

   a. Manufacturer ______________________________

   b. Model ______________________________

   c. Voltage ______________________________

   d. Brushes: Insulated or grounded? ____________________

3. Tune-up information

   a. Firing order ______________________________

   b. Cylinder location on V-type engines ____________________

c. Valve tappet clearance

	Hot	Cold
Intake	____________	____________
Exhaust	____________	____________

d. Injection pump

Make ____________________________________

Timing (static) ____________________________________

e. Low idle RPM ____________________________________

f. High idle RPM ____________________________________

4. Torque values

a. Cylinder head ________________

b. Injection nozzle/injector hold down bolt ________________

c. Nozzle line bolts ________________

5. Questions

a. What is the firing order? ____________________________

b. What are the companion cylinders (matched-throw cylinders) of this engine? ____________________________________

c. How many degrees of crankshaft rotation separate each firing pulse? ____________________________________

Objective 11

Assignment Sheet 3—Identify Valve and Piston Position During Each Stroke

Name ______________________________ Overall Rating __________

Date ______________________________

Evaluation Criterion	**Rating**
• Answers are correct	_____

Basic Skills

Reading

Critical Thinking

Directions

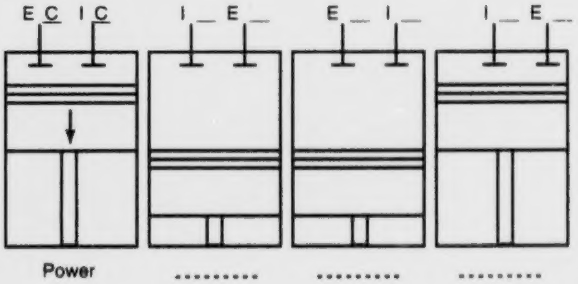
The illustration below is a four cylinder, four-stroke diesel engine. Intake valves are marked "I" and exhaust valves are marked "E." Information is given below concerning firing order, valve timing, and companion cylinders. Using this information, do the following:

1. Label each valve as either open ("O") or closed ("C"). Valves that are partially open are labeled "O".
2. Indicate piston direction by drawing an arrow in the piston skirt.
3. Write the stroke in the blank below each cylinder.

Cylinder #1 has been done for you as an example.

Firing order: 1 3 4 2
Intake valve opens: 30° before TDC
Intake valve closes: 40° after BDC
Exhaust valve opens: 30° before BDC
Exhaust valve closes: 20° after TDC
#1 piston is at 10° ATDC

Figure 1



Objective 12

Job Sheet 1—Locate TDC for #1 Piston

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Correct procedures identified for assigned vehicle	______
• Procedures completed correctly	______
• Proper tools used correctly	______
• Safety precautions observed	______
• Installed equipment functions correctly	______
• Serviced equipment meets specifications	______
• Clean-up and follow-up actions adequate	______

Basic Skills

Reading Writing Critical Thinking Employability

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, Equipment, and Materials

- Technician's common hand tools
- Appropriate service manual
- Job ticket or work order—one is included or use appropriate one provided at your facility
- Crankshaft turning tool
- Clean shop towels
- Partially disassembled diesel engine
- Others—as recommended by instructor and equipment service manual

Procedure

☐ 1. Locate and follow the appropriate procedure in the service manual.

☐ 2. Complete the accompanying worksheet with all pertinent information.

☐ 3. Thoroughly clean the engine valve cover and cylinder head.

☐ 4. Remove the valve cover.

Note: Some engines require retorquing head bolts before valve lash is set. If required, do this before proceeding to step 5.

☐ 5. Rotate the crankshaft to bring the companion cylinder for #1 piston to valve overlap. This places #1 piston close to TDC compression.

> **Caution**: To avoid injury, do **not** use the starter motor to turn the crankshaft. Use the crankshaft turning tool.

☐ 6. Adjust the valve lash for intake and exhaust valves on #1 cylinder.

☐ 7. Rotate the crankshaft to bring the next cylinder to valve overlap. Adjust the valve lash.

☐ 8. Continue steps 5 and 6 until the valve lash adjustments for all cylinders are completed.

☐ 9. Reinstall the valve cover.

☐ 10. Turn in the worksheet when finished.

☐ 11. Clean work area and return tools and materials to proper storage.

Evaluator's Comments: ______________________________

____

____

Unit 1-A, Worksheet for Job Sheet 1

Name ______________________ Date __________ Attempt number ______

Before you begin working on your assigned engine, you will need specific information to complete the job accurately. Using the appropriate service manual for your engine, locate and record the information needed below.

1. Engine identification

   a. Engine manufacturer ______________________

   b. Engine model ______________________

2. Engine specifications

   c. Firing order ______________________

   d. Head bolt torque ______________________

   e. Rocker shaft pedestal bolt torque ______________________

   f. Valve tappet clearance

	Hot	Cold
Intake	__________	__________
Exhaust	__________	__________

   g. Companion cylinders _____ _____ _____ _____ _____ _____

Job Sheet 1

PARTS LIST

QTY.	PARTS/MATERIALS	PRICE	
TOTAL PARTS/MATERIALS			

SPECIFICATIONS CHECKED

School/Work Name ____________________

Address ____________________

Phone # ____________________

Date In __________

Date Out __________

JOB TICKET

Customer Name ____________________

Customer Address ____________________

Customer Phone # ____________________

Vehicle/Equip.	Make & Model	License #/Motor #/Serial #	Speedometer

Condition reported by customer/service requested: ____________________

____

Services/repairs made: ____________________

Services/repairs made	LABOR	

Customer Authorization

I, the undersigned, have reviewed the required service and parts estimates and authorize this maintenance to be performed with the understanding that I will be notified prior to the performance of any work that significantly exceeds those estimates in time or cost.

____________________ Date __________

Technician __________

Supervisor __________

Objective 13

Job Sheet 2—Measure Bore and Stroke and Compute Engine Displacement

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Hand tools and measuring instruments selected and used correctly	______
• Measurements accurate to .005°	______
• Answers mathematically correct	______
• Shop safety rules followed	______

Basic Skills

Reading Writing Mathematics Critical Thinking Employability

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, equipment, and materials

- Technician's common hand tools
- Appropriate service manual
- Job ticket or work order—one is included or use appropriate one provided at your facility
- Crankshaft turning tool
- Ratchet, ½" drive
- Depth gauge
- Bore gauge
- Partially disassembled diesel engine
- Others—as recommended by instructor and equipment service manual

Procedure

☐ 1. Locate and follow the appropriate procedure in the service manual.

☐ 2. Complete the accompanying worksheet with all pertinent information. Some information will be calculated in the steps.

Note: Some older engines may lack engine identification tags. If basic information is known, such as engine manufacturer and engine displacement, engine data tables can be used to identify the engine.

☐ 3. Position #1 piston at TDC.

☐ 4. Using a depth gauge, measure the distance from the top of the cylinder to the top of the piston. Record this measurement in column "B" of Table 1 in the worksheet.

> **Caution**: To avoid injury, do **not** use the starter motor to turn the crankshaft. Use a crankshaft turning tool and a ½ inch drive ratchet.

☐ 5. Turn the crankshaft 180° (½ turn); observe #1 piston dropping to BDC.

☐ 6. Repeat step #2, and record the information in column "A" of Table 1.

☐ 7. To compute stroke, subtract the measurement in column "B" from the measurement in column "A." Record your answer in column "C" of Table 1.

☐ 8. To measure the bore, rotate the crankshaft 90° (¼ turn) to bring #1 piston halfway up its bore.

☐ 9. Using the top of the piston as a level, measure the bore diameter with a bore gauge. Record your answer in column "D" of Table 1.

☐ 10. Calculate the displacement for #1 cylinder. Use the following formula: Cylinder Displacement = $0.785 \times \text{Bore}^2 \times \text{Stroke}$.

☐ 11. Calculate total engine displacement by multiplying cylinder displacement times the number of cylinders. Record your answer on the line labeled "Engine Displacement" in Table 2.

Note: Other lines have been provided on Table 2 so you can conduct this exercise on other engines as your instructor may require.

☐ 12. Using the manufacturer's data tables and the information you now have, complete the rest of Table 2.

☐ 13. Have your instructor check your work.

☐ 14. Turn in worksheet when finished.

☐ 15. Clean work area and return tools and materials to proper storage.

Evaluator's Comments: ______________________________

____

____

Unit 1-A, Worksheet for Job Sheet 2

Name ______________________ Date __________ Attempt number ______

Table 1			
Piston @ BDC A	Piston @ TDC B	Stroke A–B=C	Bore D

Table 2	
a. Engine #1 ______________ Manufacturer ______________ Engine displacement __________ Engine model______________	b. Engine # 2 ______________ Manufacturer ______________ Engine displacement __________ Engine model______________
c. Engine #3 ______________ Manufacturer ______________ Engine displacement __________ Engine model______________	d. Engine #4 ______________ Manufacturer ______________ Engine displacement __________ Engine model______________

PARTS LIST

QTY.	PARTS/MATERIALS	PRICE	
TOTAL PARTS/MATERIALS			

SPECIFICATIONS CHECKED

School/Work Name ____________________

Address ____________________

Phone # ____________________

Date In ____________

Date Out ____________

JOB TICKET

Customer Name ____________________

Customer Address ____________________

Customer Phone # ____________________

Vehicle/Equip.	Make & Model	License #/Motor #/Serial #	Speedometer

Condition reported by customer/service requested: ____________________

____

Services/repairs made: ____________________

Services/repairs made	LABOR	

Customer Authorization

I, the undersigned, have reviewed the required service and parts estimates and authorize this maintenance to be performed with the understanding that I will be notified prior to the performance of any work that significantly exceeds those estimates in time or cost.

____________________ Date ____________

Technician ____________

Supervisor ____________

Unit Contents

Student Components

Student Page

Objective Sheet 2A–3

Information Sheet 2A–5

Assignment Sheets

1—Determine Required Tools for Various Tasks 2A–19
2—Evaluate Worn Engine Components 2A–21
3—Determine Possible Causes of Engine Component Failures . . . 2A–25

Job Sheets

1—Steam Clean an Engine 2A–27
2—Remove Engine Accessories and External Lines 2A–31
3—Remove Engine and Mount on an Engine Stand 2A–35
4—Engine Disassembly: Remove Cylinder Head 2A–39
5—Engine Disassembly: Remove Gear Train and Camshaft 2A–43
6—Engine Disassembly: Remove Pistons and Connecting Rods . . 2A–47
7—Engine Disassembly: Remove Cylinder Liners 2A–51
8—Engine Disassembly: Remove Crankshaft 2A–55

Objective Sheet

Unit Objective

After completing this unit, the student should be able to evaluate engine components for wear and failure, as well as remove and disassemble a diesel engine longblock and use specialty tools and precision measuring instruments to make determinations about what reconditioning operations are necessary. The student should demonstrate these competencies by completing the assignment sheets and job sheets and by scoring a minimum of 85 percent on the written test.

Specific Objectives

After completing this unit, the student should be able to:

1. Match terms related to engine disassembly procedures and analysis with their definitions.
2. Match special engine tools with their functions.
3. Match precision measuring instruments with their functions.
4. Complete statements concerning safety guidelines to follow during engine removal and disassembly.
5. Discuss good housekeeping practices and procedures.
6. Select from a list accessory components and lines that must be pulled before the engine is removed.
7. Match methods for cleaning engine components with their descriptions.
8. Discuss engine components that require measurement and analysis.
9. Match types of materials used on engine components with their applications.
10. Distinguish between types of analyses.
11. Arrange in order the eight steps of failure analysis.
12. Distinguish between normal and abnormal wear.
13. Match common types of mechanical wear with their characteristics.
14. Discuss root causes of system failures.
15. Determine required tools for various tasks. (Assignment Sheet 1)
16. Evaluate worn engine components. (Assignment Sheet 2)
17. Determine possible causes of engine component failures. (Assignment Sheet 3)

18. Steam clean an engine. (Job Sheet 1)
19. Remove engine accessories and external lines. (Job Sheet 2)
20. Remove engine and mount on an engine stand. (Job Sheet 3)
21. Disassemble engine into component parts.
    a. Remove cylinder head. (Job Sheet 4)
    b. Remove gear train and camshaft. (Job Sheet 5)
    c. Remove pistons and connecting rods. (Job Sheet 6)
    d. Remove cylinder liners. (Job Sheet 7)
    e. Remove crankshaft. (Job Sheet 8)

Information Sheet

Objective 1

Terms and definitions

a. **Beach marks**—Radial stress lines spreading outward from a fatigue crack

b. **Carbon deposits** (black)—By-products of combustion deposited on piston domes, rings, ring grooves, cylinder head(s), valves, and injector tips

c. **Cavitation**—Formation of bubbles in a fluid that occurs when the fluid is subjected to low pressures

d. **Cavitation erosion**—Gradual erosion and pitting of parts exposed to bursting cavitation bubbles

e. **Clearance**—Distance by which an object clears another or the clear space between them

f. **Contaminate**—To make unfit for use by contact with foreign material

g. **Corrode**—To weaken or destroy gradually by chemical means

h. **Defect**—Imperfection that impairs value or usability

i. **Failure**—Inability to perform the desired function; usually occurs prematurely or unexpectedly

j. **Fatigue**—Tendency of a material to break under repeated stress

k. **Foreign material**—Any extraneous material not intended to be present

Examples: Particles of steel, dirt, rust, carbon, acid, condensation (water)

l. **Indicator**—Symptom that helps identify product, operation, or maintenance problem

m. **Pitted**—Indentations or holes in the surface of an object

n. **Polished**—To make a surface smooth and shiny by friction

o. **Ratchet marks**—Tiny fractures developing between individual cracks

p. **Root cause**—Specific condition that started the problem

q. **Scored**—Marked with lines or scratches

r. **Scuffed**—Surface wear caused by friction between parts

s. **Seize**—To bond to a moving part through excessive pressure, temperature, or friction

t. **Viscosity**—Measure of a fluid's resistance to flow

u. **Wear**—Undesirable removal of material from the surface of a part

Objective 2

Special engine tools and their functions

a. **Camshaft bushing remover/installer**—Removes and replaces camshaft bushings in all gas and diesel engines

b. **Engine pre-oiler**—Pressurizes the lubricating system prior to start-up to ensure positive lubrication to all friction surfaces

c. **Engine stand**—Supports the engine's weight, allowing safe access to all engine components

d. **Fuel sight gauge**—Attaches to inlet side of fuel pump to visually identify air leaks in the suction side of the fuel delivery system

e. **Gear puller**—Uses torque or hydraulic pressure to remove gears in place

f. **Harmonic balancer puller**—Removes the harmonic balancer without damaging the inertia ring

g. **Injector removal tools**—Remove threaded, pencil-type, and "Top Stop" injectors

h. **Lift T-handles**—Replace rocker arms and provide lifting points for cylinder head removal

i. **Liner installer**—Presses the cylinder liner/cylinder pack into the cylinder block

j. **Liner puller**—Removes the cylinder liner from the block

k. **Ring compressor**—Aids installation of piston and ring assembly into the cylinder liner/cylinder bore

l. **Ring expander**—Removes and installs piston rings without breakage

m. **Rod bolt protectors**—Guide the connecting rod bolts over the crankshaft rod journal while protecting the machined surface of the journal

n. **Valve spring compressor**—Compresses the valve spring, allowing removal or installation of valve spring keepers

o. **Valve spring tester**—Indicates valve spring operating tension

Objective 3

Precision measuring instruments and their functions

a. **Ball and hole gauge**—Measures small bore diameters, such as valve guides

b. **Depth gauge**—Measures distance between two surfaces

c. **Dial bore gauge**—Measures cylinder diameter to determine wear, out-of-round, and taper

d. **Dial test indicator**—Measures back-and-forth movement of a component

e. **Diesel compression gauge**—Measures maximum cylinder pressure; gives indication of ring and valve seat wear

f. **Direct contact pyrometer**—Measures surface temperature at point of contact

g. **Feeler gauge**—Measures clearance between two mating parts

h. **Infrared pyrometer**—Measures surface temperature of an object when pointed at that object; does not require physical contact to give an accurate reading

i. **Inside micrometer**—Measures inner diameter of a cylinder, tube, or journal

j. **Magnahelic gauge**—Highly accurate gauge that measures small changes in vacuum or pressure

k. **Magnetic gauge base**—Mounts and positions dial test indicators to flat or round metal surfaces

l. **Manometer**—Measures the pressure of gases and vapors

Note: Mercury manometers are typically used in high heat applications such as exhaust manifolds. Water manometers may be used in less extreme conditions.

m. **Micrometer**—Measures outer diameter and thickness; measurement is read on a graduated scale

n. **Outside calipers**—Measures outer diameter and thickness; measurement is read on either a ruler-like scale or a gauge

o. **Precision straight-edge**—Provides an accurate reference for measuring warpage of machined surfaces

p. **Protrusion gauge** (cylinder liner height)—Measures cylinder liner lip protrusion above the cylinder block surface

q. **Radius gauge set**—Measures radii machined into the crankshaft journals

Objective 4

Safety guidelines to follow during engine removal and disassembly

a. Use hoist or chain for lifting any components over 45 pounds (100 kilograms).

b. Use guide studs/dowels to help center parts.

c. Always keep hands and fingers away from mating parts.

d. Wear all personal protective equipment as required, including safety glasses and gloves.

e. Follow all shop safety rules, and remember that "safety always comes first." Eyes and fingers are hard to replace!

Objective 5

Good housekeeping practices and procedures

a. Keep attaching hardware with their components. You may use:

- Plastic bags labeled or wire-tied to the part
- Coffee cans labeled with their contents

b. Keep workbench surface clean. It should be:

- Free of dirt and grease
- Clear of paper towels and other trash
- Clear of open containers of solvent, lubricants, etc.

c. Store parts in groups as subassemblies.

- Group parts as assemblies.
- Mark parts with paint sticks or tags.
- Mark engine brackets as they are removed.

d. Retain old parts to compare with new ones.

e. Put away tools and equipment when not in use.

Objective 6

Accessory components and lines that must be pulled (disconnected) before the engine is removed

a. Intake air duct to turbocharger inlet

b. Air conditioning compressor

c. Air lines

d. Fuel supply lines

e. Radiator hose

f. Heater hoses

g. Fan/fan clutch

h. Starting fluid injection lines

i. Wiring to sensors

j. Alternator leads

Objective 7

Methods for cleaning engine components

a. **High pressure hot water**

- For initial grease/grime removal from engine, transmission, and frame
- Avoid spraying electrical components/harnesses.

b. **Bead blasting/crushed media blasting**

- For cleaning individual hand-held components
- Non-destructive; ideal for cleaning aluminum
- Surface must be grease-free.

c. **Solvent and bristle brush**

- Larger parts are easily cleaned.
- Safe for all metals.

d. **Wire wheel**

- For rapid removal of "baked-on" grime
- Injury hazard from flying wire bristles
- Not suitable for aluminum or soft metal

e. **Abrasive disc**

- Quickly removes gasket material
- Type of disc determines suitability for different metals.

Information Sheet

Objective 8

Engine components that require measurement and analysis

a. **Cylinder head**

- Fire deck flatness
- Valve stem diameter
- Valve guide wear
- Valve condition
- Seat condition

b. **Crankshaft**

- End play
- Main journal diameter
- Rod journal diameter
- Fillet
- Journal surface color

c. **Cylinder block**

- Liner protrusion/height
- Liner counter bore
- Camshaft bearing inside diameter
- Crankshaft main bearing bore alignment
- Block-to-head mating face flatness

d. **Piston/liner**

- Liner/bore inside diameter
- Piston-to-bore clearance
- Liner surface
- Piston crown
- Piston thrust face

e. **Connecting rod**

- Wrist pin bushing inside diameter
- Big-end bore inside diameter

f. **Camshaft/lifters**

- Lobe condition
- Journal outside diameter
- Lifter condition

g. **Flywheel**

- Clutch surface condition
- Surface runout
- Starter ring gear wear

Objective 9

Types of materials used on engine components and their applications

a. **Ferrous metals** (contain iron)

- **Cast iron**—Used on cylinder blocks, cylinder heads, rocker housings, and some gears
- **Steel**—Used on crankshafts, camshafts, connecting rods, valves, and gears

b. **Non-ferrous metals and synthetics**

- **Aluminum alloys**—Used on pistons and many new parts to reduce engine weight without sacrificing strength
- **Synthetic materials, including ceramics and plastics**—Used on many replaceable parts such as lines, fittings, seals, and electronic components

Objective 10

Types of analyses

a. **Failure analysis**

- Determines conditions leading to root cause of unexpected component failure
- Primary concern is prevention of future component failure.
- Parts are inspected to determine what conditions led to the component failure.
- End result involves future change in either manufacturing, service, or operation of the engine.

b. **Wear analysis**

- Determines conditions leading to root cause of component wear
- Primary concern is reconditioning the engine for further service.
- Parts are inspected to determine what reconditioning procedures are necessary.
- End result is an engine suitable for future service.

Objective 11

Eight steps of failure analysis

a. **State the problem clearly and concisely.**

- Write it down.
- Describe the result accurately.

b. **Organize your fact-gathering.**

- Focus on most probable areas first.
- Check maintenance/operating records for the past 3-4 months.

c. **Observe and record the facts.**

- Obtain application information.
- Obtain, identify, and protect failed parts.
- Use pen and paper, photographs, and video.

d. **Think logically with the facts.**

- Determine whether damage to a specific part is root cause or result.
- Determine problem pattern.
  - — Continuous—Always present
  - — Periodic—Present under specific conditions
  - — Sporadic—Presence is erratic and unexplained.
- Determine problem trend.
  - — Stable—Severity remains the same.
  - — Increasing
  - — Decreasing

e. **Identify the most probable root cause.**

- List all possible root causes.
- Compare each suggested root cause with the problem statement (step a) and the facts (steps c and d).
- Identify which root cause fits all the facts.
- Double check your findings.
- Use root cause to identify responsible party.
    - — Manufacturer
    - — Dealer/technician
    - — Customer

f. **Communicate your findings with the responsible party.**

g. **Make repairs as directed.**

h. **Follow-up with the customer.**

Objective 12

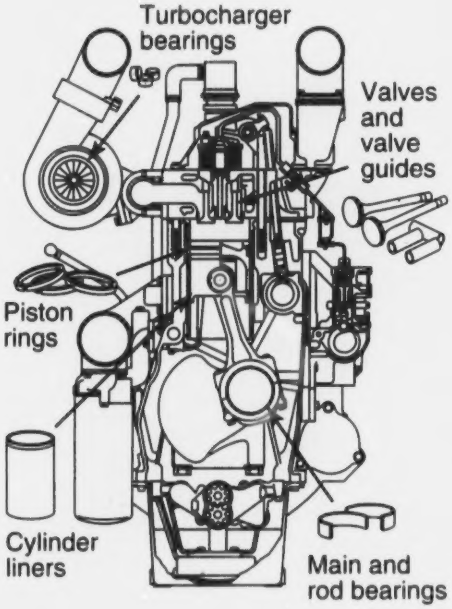
Normal and abnormal wear

a. **Normal wear**

- Expected wear with engine operation as parts push, slide, and work against each other
- Normal wear parts include:
    - — Cylinder liners
    - — Piston rings
    - — Valves, guides, and seats
    - — Main and rod bearings
    - — Turbocharger bearings and seals, if equipped

- If these basic parts are replaced before they wear out, approximately 80% of major engine failures can be eliminated.

Figure 1


Turbocharger bearings
Valves and valve guides
Piston rings
Cylinder liners
Main and rod bearings

© Caterpillar Inc. Used with permission

b. **Abnormal wear**

- Unexpected wear that can lead to premature engine failure
- Generally results from incorrect maintenance or improper operating technique such as:
  - Wrong lubricant
  - Too long between oil changes
  - Lack of coolant additives
  - Inadequate engine warm-up

- Abnormal wear parts include:
  - Cylinder heads
  - Cylinder blocks
  - Crankshafts
  - Camshafts
  - Pistons and connecting rods

Objective 13

Common types of mechanical wear and their characteristics

a. **Abrasive wear**

- Occurs when hard particles such as dirt or debris get trapped in the lubricating film between moving parts
- Heat build-up occurs, weakening parts. Soft metal parts are damaged first.
- Accounts for majority of wear failures (over 50%)

b. **Adhesive wear**

- Consists of localized bonding between contacting surfaces that leads to material transfer from one surface to the other or loss of material from either surface
- Is frequently referred to as scoring, scuffing, seizing, or galling
- Contact between the moving surfaces produces intense heat. Metal surfaces begin a cycle of welding/shearing until one part is destroyed.
- Caused by inadequate lubrication between moving surfaces

c. **Corrosive wear**

- Occurs when metal surfaces are exposed to an electrolyte, dissimilar metals (for example, aluminum in contact with steel), or high temperatures
- It is typically a reaction between ferrous and non-ferrous metals.
- Metal is removed by electrochemical action.

d. **Erosive wear** (erosion)

- Occurs when small hard particles, carried by fast-moving fluids, strike metal surfaces at high speeds

- Metal parts suffer damage from impact and abrasive wear.
- Erosion is greatly accelerated when worn parts begin to break up.

e. **Cavitation erosion**

- Occurs when vapor bubbles in a fluid strike a metal surface
- As the bubbles burst, they send a fluid "jet" against the metal surface at supersonic speeds.
- Pits form as small metal particles are blown away.

f. **Fretting wear**

- Occurs when tight fitting (shift or press fit) parts are allowed to move slightly against each other such as by vibration
- Flash welding creates small pits.
- The particles interfere with running clearances, affecting lubrication.

Objective 14

Root causes of system failures

a. **Fuel system failures**

- Wrong fuel
  - Incorrect grade
  - Incorrect sulfur level
- Contaminated fuel (biological, dirt, or water)
- Incorrect installation of components or lines
- Incorrect timing of fuel injectors

b. **Cooling system failures**

Note: Over 40% of engine failures result from cooling system problems. The cooling system is most critical to engine life.

- Supplemental coolant additive (SCA) problems
  - Too little or too much
  - Incorrect or incompatible type
  - Deteriorated or low quality

- Coolant problems
  - Incorrect mix of water, antifreeze, and additives
  - Contaminated coolant (metal, dirt, oil)
- Faulty cooling system components (thermostat, fan, pump) that cause engine to run too hot or too cool

c. **Lubrication system failures**

- Wrong lubricant
  - Incorrect viscosity (too thick or too thin)
  - Incorrect weight or grade
- Too little (or marginal) lubricant
- Contaminated lubricant (metals, dirt, coolant)

  Note: Contaminated oil is the single largest cause of engine crankshaft bearing failures.
- Clogged oil filters

  Note: Metal in the filter indicates internal engine wear.

d. **Air induction and exhaust system failures**

- Air or exhaust restrictions
  - Plugged air filters
  - Malfunctioning turbochargers or other components
- Dirty air

Objective 15

Assignment Sheet 1—Determine Required Tools for Various Tasks

Name ______________________ Overall Rating __________

Date ______________________

Evaluation Criteria	Rating
• Correct choice of manual and relevant repair section	______
• Engine tools correctly recorded	______

Basic Skills

Reading Writing Critical Thinking

Directions

Using the appropriate engine service manual, list the tools required to do each of the tasks below.

1. To remove heavy cylinder head ______________________
2. To remove cylinder liners ______________________
3. To remove heavy crankshaft ______________________
4. To remove valves from head ______________________
5. To measure out-of-round and taper of cylinder bore ______________________

   ____
6. To measure diameter of rod and main journals on crankshaft ______________________

   ____

Objective 16

Assignment Sheet 2—Evaluate Worn Engine Components

Name ______________________ Overall Rating __________

Date ______________________

Evaluation Criteria	Rating
• Correct identification of wear	______
• Appropriate evaluation of reusability	______

Basic Skills

Reading Writing Critical Thinking

Directions

Examine the following engine components provided by your instructor. For each component, determine if wear is present, and fill in each blank with the information required.

1. Crankshaft
   a. Wear present?__________
   b. Type of wear__________
   c. Description/location______________________________
   d. Normal or abnormal?______________________________
   e. Is this part reusable or does it need to be replaced?__________
2. Piston
   a. Wear present?__________
   b. Type of wear__________
   c. Description/location______________________________
   d. Normal or abnormal?______________________________
   e. Is this part reusable or does it need to be replaced?__________

3. Piston rings

   a. Wear present?___________

   b. Type of wear_____________

   c. Description/location______________________________________

   d. Normal or abnormal?_____________________________________

   e. Is this part reusable or does it need to be replaced?_____________

4. Cylinder block firedeck

   a. Wear present?___________

   b. Type of wear_____________

   c. Description/location______________________________________

   d. Normal or abnormal?_____________________________________

   e. Is this part reusable or does it need to be replaced?_____________

5. Cylinder liner (inside)

   a. Wear present?___________

   b. Type of wear_____________

   c. Description/location______________________________________

   d. Normal or abnormal?_____________________________________

   e. Is this part reusable or does it need to be replaced?_____________

6. Cylinder liner (outside)

   a. Wear present?___________

   b. Type of wear_____________

   c. Description/location______________________________________

   d. Normal or abnormal?_____________________________________

   e. Is this part reusable or does it need to be replaced?_____________

7. Valve
   a. Wear present?___________
   b. Type of wear_____________
   c. Description/location_______________________________________
   d. Normal or abnormal?_______________________________________
   e. Is this part reusable or does it need to be replaced?_____________
8. Valve guide
   a. Wear present?___________
   b. Type of wear_____________
   c. Description/location_______________________________________
   d. Normal or abnormal?_______________________________________
   e. Is this part reusable or does it need to be replaced?_____________
9. Main bearing insert
   a. Wear present?___________
   b. Type of wear_____________
   c. Description/location_______________________________________
   d. Normal or abnormal?_______________________________________
   e. Is this part reusable or does it need to be replaced?_____________
10. Connecting rod
   a. Wear present?___________
   b. Type of wear_____________
   c. Description/location_______________________________________
   d. Normal or abnormal?_______________________________________
   e. Is this part reusable or does it need to be replaced?_____________

Objective 17

Assignment Sheet 3—Determine Possible Causes of Engine Component Failures

Name ______________________________ Overall Rating __________

Date ______________________________

Evaluation Criteria	Rating
• Correct choice of service manual and section	______
• Correct identification of root cause	______

Basic Skills

Reading Writing Critical Thinking

Directions

Examine the following engine component failures provided by your instructor. Using appropriate service manuals and troubleshooting guides, describe the problem and determine one possible cause for each failure.

1. Connecting rod
   a. Description of failure ______________________________
   b. Possible cause ______________________________
2. Bolt
   a. Description of failure ______________________________
   b. Possible cause ______________________________
3. Cylinder liner
   a. Description of failure ______________________________
   b. Possible cause ______________________________
4. Bearing insert
   a. Description of failure ______________________________
   b. Possible cause ______________________________

Assignment Sheet 3

5. Camshaft lobe

   a. Description of failure______________________________

   b. Possible cause__________________________________

6. Crankshaft

   a. Description of failure______________________________

   b. Possible cause__________________________________

7. Cam gear

   a. Description of failure______________________________

   b. Possible cause__________________________________

Objective 18

Job Sheet 1—Steam Clean an Engine

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	**Rating**
• Correct procedures identified for assigned vehicle	______
• Procedures completed correctly	______
• Proper tools used correctly	______
• Safety precautions observed	______
• Clean-up and follow-up actions adequate	______

Basic Skills

Reading Writing Critical Thinking Employability

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, Equipment, and Materials

- Technician's common hand tools
- Appropriate service manual
- Job ticket or work order—one is included or use appropriate one provided at your facility
- Safety equipment
- High pressure hot water washer
- Degreaser (if required)
- Shop towels
- Compressed air source
- Assigned vehicle to work on
- Others—as recommended by instructor and equipment service manual

Guidelines

- Wear protective clothing when working with high pressure steam or hot water. Water, soap solution, and grease being splashed back on you will be HOT.

- Avoid spraying water on the alternator, starter, injector pump, or wiring harnesses.

- Do not spray the radiator core with high pressure water. This will bend and damage the fins, reducing the radiator's cooling ability.

- Wear eye protection if using compressed air to dry the engine.

Job Sheet 1

Procedure

☐ 1. Locate and follow the appropriate procedure in the service manual.

☐ 2. Complete the accompanying job ticket with all pertinent information.

☐ 3. Set the parking brake and chock the wheels.

☐ 4. Disconnect the battery ground cable.

☐ 5. If the engine has been running recently, allow it to cool. If the engine is too hot to touch, it's too hot to clean.

☐ 6. Use plastic and duct tape to cover the alternator, electrical connectors, and any electronic fuel control components on the engine. Check the service manual for component identification and location.

☐ 7. If recommended by your instructor, spray the engine with a degreasing solution, and allow it to soak in for a few minutes.

☐ 8. Begin spraying the engine at the oil pan, and work UP. When you reach the valve covers, rinse the engine off, working DOWN, ending at the oil pan. This prevents runoff from diluting the degreaser on the rest of the engine.

☐ 9. Clean the engine mounts, bell housing, and frame rails.

☐ 10. After thoroughly rinsing the engine, dry it with compressed air. This speeds drying time and minimizes the chance for surface rust to form.

☐ 11. Remove the plastic and duct tape.

☐ 12. Turn in job ticket when finished.

☐ 13. Clean work area and return tools and materials to proper storage.

Evaluator's Comments: ____________________________________

____

____

PARTS LIST

QTY.	PARTS/MATERIALS	PRICE	
TOTAL PARTS/MATERIALS			

SPECIFICATIONS CHECKED

School/Work Name ____________________

Address ____________________

Phone # ____________________

Date In ____________

Date Out ____________

JOB TICKET

Customer Name ____________________

Customer Address ____________________

Customer Phone # ____________________

Vehicle/Equip.	Make & Model	License #/Motor #/Serial #	Speedometer

Condition reported by customer/service requested: ____________________

Services/repairs made: ____________________

LABOR	

Customer Authorization

I, the undersigned, have reviewed the required service and parts estimates and authorize this maintenance to be performed with the understanding that I will be notified prior to the performance of any work that significantly exceeds those estimates in time or cost.

____________________ Date ____________

Technician ____________

Supervisor ____________

Objective 19

Job Sheet 2—Remove Engine Accessories and External Lines

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Correct procedures identified for assigned vehicle	______
• Procedures completed correctly	______
• Proper tools used correctly	______
• Safety precautions observed	______
• Clean-up and follow-up actions adequate	______

Basic Skills

Reading Writing Critical Thinking Employability

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, Equipment, and Materials

- Technician's common hand tools
- Appropriate service manual
- Job ticket or work order—one is included or use appropriate one provided at your facility
- Safety equipment
- Drain pans
- Shop towels
- Assigned vehicle to work on
- Others—as recommended by instructor and equipment service manual

Guidelines

- Place used lubricants and coolants in approved waste containers.
- Clean up spills immediately. Antifreeze and oil make shop floors very slippery.
- Don't allow coolant to remain on painted surfaces; it will damage the finish.

Procedure

☐ 1. Locate and follow the appropriate procedure in the service manual.

☐ 2. Complete the accompanying job ticket with all pertinent information.

☐ 3. Set the parking brake and chock the wheels.

☐ 4. Drain the cooling system. You will find petcocks at the bottom of the radiator and on the side of the engine block. The engine service manual will show you the specific locations. Check with your instructor to see whether the coolant will be recycled or replaced.

☐ 5. Drain the engine oil. When the oil pan is empty, reinstall the drain plug.

☐ 6. Disconnect and plug the fuel line at the transfer pump.

☐ 7. Remove the air duct from the air filter to the turbocharger (or intake manifold) inlet.

☐ 8. Disconnect the exhaust pipe at the turbocharger (or exhaust manifold) outlet.

☐ 9. Remove the fan belts.

☐ 10. Remove the fan blades and fan clutch.

☐ 11. Remove the upper and lower radiator hoses.

☐ 12. Disconnect the heater hoses (if applicable) at the block. Plug the open ends of the hoses to prevent losing coolant from the heater core.

☐ 13. Remove the air conditioner compressor. DO NOT disconnect the refrigerant lines. Secure the compressor to the frame rail where it won't be disturbed.

☐ 14. Disconnect the air lines from the air compressor (air brakes), and remove the air compressor.

☐ 15. Remove the starter fluid injection line (if applicable).

☐ 16. Disconnect the throttle linkage from the injector pump.

☐ 17. Label and disconnect the following electrical connectors/harnesses:

  ☐ a. Alternator leads

  ☐ b. Starter solenoid battery cable and starter wire

  ☐ c. Coolant temperature sending unit

  ☐ d. Oil pressure sending unit

  ☐ e. Block-mounted fuel control computer

  - ☐ f. Glow plug power wire from relay (if applicable)
  - ☐ g. Jake Brake®

☐ 18. Remove the starter.

☐ 19. Remove the alternator.

☐ 20. Turn in job ticket when finished.

☐ 21. Clean work area and return tools and materials to proper storage.

Evaluator's Comments: ______________________________________

____

____

Job Sheet 2

PARTS LIST

QTY.	PARTS/MATERIALS	PRICE	
TOTAL PARTS/MATERIALS			

SPECIFICATIONS CHECKED

School/Work Name ____________________

Address ____________________

Phone # ____________________

Date In ____________

Date Out ____________

JOB TICKET

Customer Name ____________________

Customer Address ____________________

Customer Phone # ____________________

Vehicle/Equip.	Make & Model	License #/Motor #/Serial #	Speedometer

Condition reported by customer/service requested: ____________________

____

Services/repairs made: ____________________

	LABOR	

Customer Authorization

I, the undersigned, have reviewed the required service and parts estimates and authorize this maintenance to be performed with the understanding that I will be notified prior to the performance of any work that significantly exceeds those estimates in time or cost.

____________________ Date ____________

Technician ____________

Supervisor ____________

Objective 20

Job Sheet 3—Remove Engine and Mount on an Engine Stand

Name ____________________ Attempt Number ________

Date ____________________ Overall Rating ________

Evaluation Criteria	Rating
• Correct procedures identified for assigned vehicle	______
• Procedures completed correctly	______
• Proper tools used correctly	______
• Safety precautions observed	______
• Clean-up and follow-up actions adequate	______

Basic Skills

Reading Writing Critical Thinking Employability

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, Equipment, and Materials

- Technician's common hand tools
- Appropriate service manual
- Job ticket or work order—one is included or use appropriate one provided at your facility
- Safety equipment
- Transmission jack
- Engine hoist and adapters
- Engine stand
- Shop towels
- Assigned vehicle to work on
- Others—as recommended by instructor and equipment service manual

Guidelines

- Diesel engines are HEAVY. Make sure the hoisting adapters are securely mounted, and operate the lifting equipment with caution.

- Make sure the transmission is securely supported.

Procedure

☐ 1. Locate and follow the appropriate procedure in the service manual.

☐ 2. Complete the accompanying job ticket with all pertinent information.

☐ 3. Set the parking brake and chock the wheels.

☐ 4. If the transmission is not firmly supported by the frame (front and back), place a transmission jack under it and secure the transmission to the jack pad with chains.

☐ 5. Attach the hoist and lifting adapter(s) to the engine. Raise the hoist to take up the slack in the lifting chain.

☐ 6. Loosen and remove the motor mount bolts.

☐ 7. Raise the hoist further to take the pressure off the mounts. Reposition/raise the transmission jack if necessary.

☐ 8. Loosen and remove the bolts holding the bell housing to the engine.

☐ 9. Break the engine free from the bell housing, moving it forward to clear the transmission input shaft from the clutch assembly.

☐ 10. Raise the engine to clear the frame rails and remove it from the vehicle.

Note: To move the engine across the shop floor, lower it almost to floor-level. This keeps the center of gravity low.

☐ 11. Mount the engine stand support adapter to the engine; then fit the adapter to the engine stand. Remove the hoist lifting chains.

☐ 12. Turn in job ticket when finished.

☐ 13. Clean work area and return tools and materials to proper storage.

Evaluator's Comments: ______________________________

____

____

539

PARTS LIST

QTY.	PARTS/MATERIALS	PRICE	
TOTAL PARTS/MATERIALS			

SPECIFICATIONS CHECKED

School/Work Name ____________________

Address ____________________

Phone # ____________________

Date In ____________

Date Out ____________

JOB TICKET

Customer Name ____________________

Customer Address ____________________

Customer Phone # ____________________

Vehicle/Equip.	Make & Model	License #/Motor #/Serial #	Speedometer

Condition reported by customer/service requested: ____________________

____

Services/repairs made: ____________________

	LABOR	

Customer Authorization

I, the undersigned, have reviewed the required service and parts estimates and authorize this maintenance to be performed with the understanding that I will be notified prior to the performance of any work that significantly exceeds those estimates in time or cost.

____________________ Date ____________

Technician ____________

Supervisor ____________

Job Sheet 3

Objective 21

Job Sheet 4—Engine Disassembly: Remove Cylinder Head

Name ____________________ Attempt Number ________

Date ____________________ Overall Rating ________

Evaluation Criteria	Rating
• Correct procedures identified for assigned vehicle	______
• Procedures completed correctly	______
• Proper tools used correctly	______
• Safety precautions observed	______
• Clean-up and follow-up actions adequate	______

Basic Skills

Reading Writing Critical Thinking Employability

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, Equipment, and Materials

- Technician's common hand tools
- Appropriate service manual
- Job ticket or work order—one is included or use appropriate one provided at your facility
- Safety equipment
- Pry bar
- Straight-edge
- Feeler gauge set (.003″ through .015″)
- Gasket scraper
- Wire brush
- Compressed air
- Engine hoist and adapters
- Solvent
- Shop towels
- Clear plastic bags or recycled coffee cans
- Assigned engine to work on
- Others—as recommended by instructor and equipment service manual

Guidelines

- Place removed fasteners in labeled clear plastic bags or coffee cans.

- Use the hoist to lift and maneuver the cylinder head.

Job Sheet 4

Procedure

☐ 1. Locate and follow the appropriate procedure in the service manual.

☐ 2. Complete the accompanying job ticket with all pertinent information.

☐ 3. Remove the valve covers.

☐ 4. Remove wiring harness(es) for electronic injectors, Jake Brakes®, etc. Label and store all Jake Brake® fasteners and components together.

☐ 5. Disconnect and remove the fuel supply lines.

☐ 6. Remove the rocker arm assemblies. Check the shaft and the rocker arm bushings for scoring. If scoring is present, note this on the job ticket.

☐ 7. Remove push rods (if used). Check the push rods for straightness by rolling them on a flat piece of metal. Note any bent push rods on the job ticket.

☐ 8. Loosen each cylinder head bolt ½ turn. Use the torque sequence that the engine service manual gives for tightening the cylinder head bolts. Follow the sequence again, and loosen the bolts one full turn. Finally, remove the bolts completely and store them in a plastic bag.

☐ 9. Use the hoist and chains to lift the head from the block and set it on the bench. Place the head upside down so that the fire deck faces up.

☐ 10. Use the gasket scraper and the abrasive wheel to remove any traces of gasket material from the fire deck. When through, wipe the surface with a solvent-moistened shop towel.

☐ 11. Lay the straight-edge lengthwise along the fire deck. Try to slip a feller gauge between the straight-edge and the fire deck. On the job ticket, record the largest gauge that fits under the straight-edge.

☐ 12. Turn in job ticket when finished.

☐ 13. Clean work area and return tools and materials to proper storage.

Evaluator's Comments: ______________________________

____

____

PARTS LIST

QTY.	PARTS/MATERIALS	PRICE	
TOTAL PARTS/MATERIALS			

SPECIFICATIONS CHECKED

School/Work Name ____________________

Address ____________________

Phone # ____________________

Date In ____________

Date Out ____________

JOB TICKET

Customer Name ____________________

Customer Address ____________________

Customer Phone # ____________________

Vehicle/Equip.	Make & Model	License #/Motor #/Serial #	Speedometer

Condition reported by customer/service requested: ____________________

Services/repairs made: ____________________

	LABOR	

Customer Authorization

I, the undersigned, have reviewed the required service and parts estimates and authorize this maintenance to be performed with the understanding that I will be notified prior to the performance of any work that significantly exceeds those estimates in time or cost.

____________________ Date ____________

Technician ____________

Supervisor ____________

Objective 22

Job Sheet 5—Engine Disassembly: Remove Gear Train and Camshaft

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	**Rating**
• Correct procedures identified for assigned vehicle	______
• Procedures completed correctly	______
• Proper tools used correctly	______
• Safety precautions observed	______
• Clean-up and follow-up actions adequate	______

Basic Skills

Reading Writing Critical Thinking Employability

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, Equipment, and Materials

- Technician's common hand tools
- Appropriate service manual
- Job ticket or work order—one is included or use appropriate one provided at your facility
- Safety equipment
- Damper remover
- Gear puller
- Shop towels
- All Thread (threaded rod) 18–24" long
- Assigned engine to work on
- Others—as recommended by instructor and equipment service manual

Guidelines

- Valve lifters MUST remain matched with their camshaft lobe. Don't mix them up.

- This procedure is intended as a general overview. Use the specific procedure listed in your engine service manual.

Procedure

☐ 1. Locate and follow the appropriate procedure in the service manual.

☐ 2. Complete the accompanying job ticket with all pertinent information.

☐ 3. Remove the vibration damper. Consult your engine service manual for the specific procedure and tools for this.

☐ 4. Remove the injector pump.

☐ 5. Remove the timing drive cover. Closely inspect the gear train for timing marks. Are they marked as shown in the service manual? If you have any questions, talk to your instructor.

☐ 6. Remove accessories from the front drive. Your engine service manual contains the procedures for this.

☐ 7. Remove side covers (if necessary) and remove the cam followers.

Note: Keep the cam followers matched to the cam lobe they ride on. Reinstalling a cam follower on a different lobe will cause rapid lobe wear and failure.

☐ 8. Remove the cam gear retaining bolt. Install a piece of All-Thread (threaded rod) 18″–24″ long. This will serve as a handle when removing the camshaft.

☐ 9. Using the All-Thread as a lever to keep the cam level, pull the camshaft from the block. Be careful not to let the lobes or journals strike any inside metal edges. This will damage the cam, making it useless for further service.

☐ 10. Visually inspect the cam. Do you see signs of overheating (bluish tint) or lack of lubrication (scoring)? If so, note it on your job ticket.

☐ 11. Turn in job ticket when finished.

☐ 12. Clean work area and return tools and materials to proper storage.

Evaluator's Comments: ______________________________

____

____

PARTS LIST

QTY.	PARTS/MATERIALS	PRICE	
TOTAL PARTS/MATERIALS			

SPECIFICATIONS CHECKED

School/Work Name ____________________
Address ____________________
Phone # ____________________

Date In ____________
Date Out ____________

JOB TICKET

Customer Name ____________________
Customer Address ____________________
Customer Phone # ____________________

Vehicle/Equip.	Make & Model	License #/Motor #/Serial #	Speedometer

Condition reported by customer/service requested: ____________________

Services/repairs made: ____________________

LABOR	

Customer Authorization

I, the undersigned, have reviewed the required service and parts estimates and authorize this maintenance to be performed with the understanding that I will be notified prior to the performance of any work that significantly exceeds those estimates in time or cost.

____________________ Date ____________

Technician ____________
Supervisor ____________

Objective 23

Job Sheet 6—Engine Disassembly: Remove Pistons and Connecting Rods

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Correct procedures identified for assigned vehicle	______
• Procedures completed correctly	______
• Proper tools used correctly	______
• Safety precautions observed	______
• Clean-up and follow-up actions adequate	______

Basic Skills

Reading Writing Critical Thinking Employability

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, Equipment, and Materials

- Technician's common hand tools
- Appropriate service manual
- Job ticket or work order—one is included or use appropriate one provided at your facility
- Safety equipment
- Bench vise
- Connecting rod guide pins
- Cylinder liner retainer
- Hammer handle
- Crocus cloth
- Shop towels
- Clear plastic bags
- Assigned engine to work on
- Others—as recommended by instructor and equipment service manual

Guidelines

- Do not use force when removing pistons. A steady push will get the job done and prevent damage to the piston, rings, or liner.

- Do not work on more than one cylinder at a time. This will prevent mix-ups and lost parts.

Procedure

☐ 1. Locate and follow the appropriate procedure in the service manual.

☐ 2. Complete the accompanying job ticket with all pertinent information.

☐ 3. Remove the oil pan. Place the pan bolts in a labeled plastic bag.

☐ 4. Check the rod and rod cap to make sure they are marked with that cylinder's number. If no number is visible, use a metal stamp to label the two pieces.

☐ 5. Use crocus cloth to remove the carbon ridge present at the top of the liner.

☐ 6. Install the liner retainer.

☐ 7. Working on one cylinder at a time, remove the rod cap bolts, rod cap, and bearing.

☐ 8. Install the plastic rod guides; then use the hammer handle to push the piston and rod up out of the liner.

☐ 9. Reassemble the piston/rod and rod cap.

☐ 10. Repeat steps #4 thru #8 for the remaining pistons. Place each piston and rod assembly in order on the workbench.

☐ 11. Inspect each piston and look for the following:

  ☐ a. Pits or cracks in the combustion surface of the piston

  ☐ b. Deep scratches on the piston skirt

  ☐ c. Damage to the ring area of the piston

  ☐ d. Broken rings

  ☐ e. Twisted or bent connecting rod

☐ 12. Note any problems on the job ticket.

☐ 13. Turn in job ticket when finished.

☐ 14. Clean work area and return tools and materials to proper storage.

Evaluator's Comments: ______________________________________

____

____

PARTS LIST

QTY.	PARTS/MATERIALS	PRICE	
TOTAL PARTS/MATERIALS			

SPECIFICATIONS CHECKED

School/Work Name ____________________
Address ____________________
Phone # ____________________

Date In ____________
Date Out ____________

JOB TICKET

Customer Name ____________________
Customer Address ____________________
Customer Phone # ____________________

Vehicle/Equip.	Make & Model	License #/Motor #/Serial #	Speedometer

Condition reported by customer/service requested: ____________________

Services/repairs made: ____________________

LABOR	

Customer Authorization

I, the undersigned, have reviewed the required service and parts estimates and authorize this maintenance to be performed with the understanding that I will be notified prior to the performance of any work that significantly exceeds those estimates in time or cost.

____________________ Date ____________

Technician ____________
Supervisor ____________

Objective 24

Job Sheet 7—Engine Disassembly: Remove Cylinder Liners

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Correct procedures identified for assigned vehicle	______
• Procedures completed correctly	______
• Proper tools used correctly	______
• Safety precautions observed	______
• Clean-up and follow-up actions adequate	______

Basic Skills

Reading Writing Critical Thinking Employability

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, Equipment, and Materials

- Technician's common hand tools
- Appropriate service manual
- Job ticket or work order—one is included or use appropriate one provided at your facility
- Safety equipment
- Liner removal tool
- Shop towels
- Assigned engine to work on
- Others—as recommended by instructor and equipment service manual

Guidelines

- Do not remove more than one liner at a time. This will prevent mix-ups.

- Check the liner removal tool adapter plate for correct size. It must fit the liner but not touch the block. An adapter that is too large will damage the block.

Procedure

☐ 1. Locate and follow the appropriate procedure in the service manual.

☐ 2. Complete the accompanying job ticket with all pertinent information.

☐ 3. Use the manufacturer's instructions that are supplied with the liner removal tool.

☐ 4. Install the liner removal tool, making sure the correct size adapter is being used. The adapter must not touch the block itself.

☐ 5. Following the manufacturer's instructions, remove the liner from the block.

☐ 6. Label the liner with its cylinder number, and place it on the workbench with its piston and rod.

☐ 7. As you pull each liner, inspect it for the following:

  ☐ a. Pitting on the outside liner surface (cavitation erosion)

  ☐ b. Scratches or gouges along the inside walls of the liner

☐ 8. Note any problems on the job ticket.

☐ 9. Turn in job ticket when finished.

☐ 10. Clean work area and return tools and materials to proper storage.

Evaluator's Comments: ______________________________

____

____

PARTS LIST

QTY.	PARTS/MATERIALS	PRICE	
TOTAL PARTS/MATERIALS			

SPECIFICATIONS CHECKED

School/Work Name ______________________
Address ______________________
Phone # ______________________

Date In __________
Date Out __________

JOB TICKET

Customer Name ______________________
Customer Address ______________________
Customer Phone # ______________________

Vehicle/Equip.	Make & Model	License #/Motor #/Serial #	Speedometer

Condition reported by customer/service requested: ______________________

Services/repairs made: ______________________

LABOR	

Customer Authorization

I, the undersigned, have reviewed the required service and parts estimates and authorize this maintenance to be performed with the understanding that I will be notified prior to the performance of any work that significantly exceeds those estimates in time or cost.

______________________ Date __________

Technician __________
Supervisor __________

Objective 25

Job Sheet 8—Engine Disassembly: Remove Crankshaft

Name ______________________ Attempt Number ______

Date ______________________ Overall Rating ______

Evaluation Criteria	Rating
• Correct procedures identified for assigned vehicle	______
• Procedures completed correctly	______
• Proper tools used correctly	______
• Safety precautions observed	______
• Clean-up and follow-up actions adequate	______

Basic Skills

Reading Writing Critical Thinking Employability

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, Equipment, and Materials

- Technician's common hand tools
- Appropriate service manual
- Job ticket or work order—one is included or use appropriate one provided at your facility
- Safety equipment
- Pry bar
- Engine hoist
- Crankshaft lifting tool
- Shop towels
- Assigned engine to work on
- Others—as recommended by instructor and equipment service manual

Guidelines

- The crankshaft is HEAVY. Use care when handling it. Keep fingers and hands from between the crankshaft and the block.

- Do not attempt to lift the crankshaft out of the block by hand. Use the lifting tool and the engine hoist.

Procedure

☐ 1. Locate and follow the appropriate procedure in the service manual.

☐ 2. Complete the accompanying job ticket with all pertinent information.

☐ 3. Turn the engine upside down so that the crankshaft is easily accessible.

- ☐ 4. Mark the main bearing caps. The caps are matched to a specific main bearing. DO NOT mix them up.
- ☐ 5. Loosen and remove the main bearing capscrews. Remove each main bearing cap and set it on the bench in the order it was removed. (It may be necessary to use the pry bar to remove the caps.)
- ☐ 6. Place the crankshaft lifting tool around the center throws, and use the hoist to lift the crankshaft out of the block.
- ☐ 7. Lay the crankshaft on the workbench. Inspect it for the following:
    - ☐ a. Rough journal surfaces
    - ☐ b. Damage to counterweights
- ☐ 8 Note any problems on the job ticket.
- ☐ 9. To prevent warpage, the crankshaft must be stored upright. When your inspections are completed, stand the crankshaft on its flywheel hub, and secure it firmly to prevent falling.
- ☐ 10. Remove the bearing shells from the block and from the caps. Place each cylinder's bearing shells with its piston and liner.
- ☐ 11. Reinstall the bearing caps and capscrews on the cylinder block.
- ☐ 12. Turn in job ticket when finished.
- ☐ 13. Clean work area and return tools and materials to proper storage.

Evaluator's Comments: ______________________________

____

____

PARTS LIST

QTY.	PARTS/MATERIALS	PRICE	
TOTAL PARTS/MATERIALS			

SPECIFICATIONS CHECKED

School/Work Name ____________________

Address ____________________

Phone # ____________________

Date In ____________

Date Out ____________

JOB TICKET

Customer Name ____________________

Customer Address ____________________

Customer Phone # ____________________

Vehicle/Equip.	Make & Model	License #/Motor #/Serial #	Speedometer

Condition reported by customer/service requested: ____________________

Services/repairs made: ____________________

LABOR	

Customer Authorization

I, the undersigned, have reviewed the required service and parts estimates and authorize this maintenance to be performed with the understanding that I will be notified prior to the performance of any work that significantly exceeds those estimates in time or cost.

____________________ Date ____________

Technician ____________

Supervisor ____________

Unit Contents

Student Components

Student Page

Objective Sheet 1B–3

Information Sheet 1B–5

Job Sheets

1—Service and Install Oil Pump and Oil Pump Drive Components 1B–15
2—Service and Inspect Lubrication System Screens and Pipes 1B–19
3—Service and Inspect Oil Pressure Regulator Valve and Bypass Valve 1B–23
4—Service and Inspect Oil Cooler and Lines 1B–27

Objective Sheet

Unit Objective

After completing this unit, the student should be able to identify and service lubrication system components. The student should demonstrate these competencies by completing the job sheets and by scoring a minimum of 85 percent on the written test.

Specific Objectives

After completing this unit, the student should be able to:

1. Match terms related to lubrication systems with their definitions.
2. Identify the basic components of a lubrication system.
3. Match lubrication system components with their functions.
4. Match basic types of oil filters with their descriptions of operation.
5. Distinguish between the basic oil pump designs and their operation.
6. Identify basic oil cooler designs.
7. Distinguish among types of oil coolers according to descriptions of their operation.
8. List sources of oil contamination.
9. Complete statements concerning lubrication system monitor operation.
10. Complete statements concerning API use codes.
11. Discuss factors to consider when choosing an engine oil.
12. Service and install oil pump and oil pump drive components. (Job Sheet 1)
13. Service and inspect lubrication system screens and pipes. (Job Sheet 2)
14. Service and inspect oil pressure regulator valve and bypass valve. (Job Sheet 3)
15. Service and inspect oil cooler and lines. (Job Sheet 4)

Information Sheet

Objective 1

Terms and definitions

a. **Additives**—Chemicals added to the oil to provide extra performance

b. **Antidrain check valve**—Prevents oil from draining out of the filters and back into the oil pan when the engine is stopped

c. **American Petroleum Institute (API)**—Association that issues engine oil classifications based on performance during standardized tests

d. **American Society for Testing and Materials (ASTM)**—Association that establishes minimum performance standards for different classifications of engine lubricating oil

e. **Contaminant**—Any unwanted material in a fluid or lubricant

f. **Filter**—Device that removes contaminants from fluids or lubricant

g. **Gallery**—Pipe or passageway in the engine used to carry engine oil from one area to another

h. **Inhibitor**—Chemical which dissolves in water to form a rustproof film on metal

i. **Military specifications (MIL)**—Oil specifications prepared by the federal government for specific military applications

j. **Multigrade oil**—Oil that has been modified to behave as a light oil in cold temperatures, while acting as a heavy oil when hot

k. **Oil pan**—Reservoir for engine oil; the pan sides also provide a surface for heat transfer from the hot oil to the atmosphere

l. **Particulate**—Substance made up of minute separate particles

m. **Pressure gauge**—Indicates lubrication system pressure when the engine is running

n. **Society of Automotive Engineers (SAE)**—Association that developed a rating system for oil viscosity

o. **Strainer**—Coarse filter usually designed to prevent large items such as rocks and bolts from entering the system

p. **Temperature gauge**—Indicates the temperature of the oil in the oil pan

q. **Viscometer**—Instrument used to measure viscosity

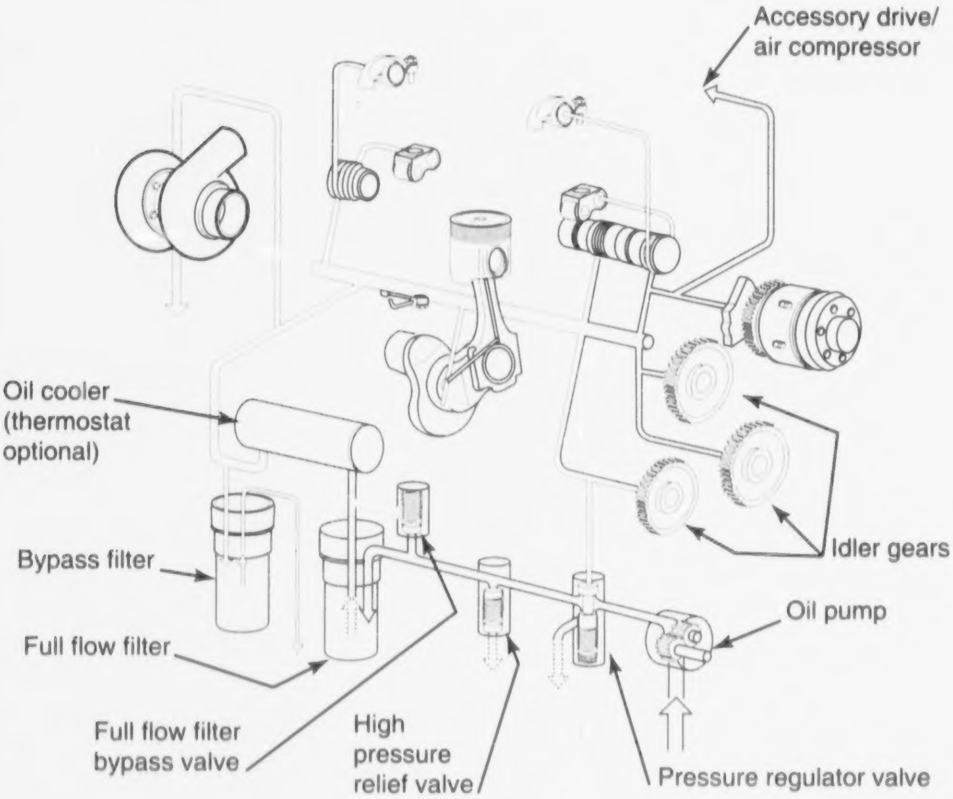
r. **Viscosity**—Measure of a fluid's resistance to flow (at a given temperature)

Information Sheet

Objective 2

Lubrication system components

Figure 1


Accessory drive/ air compressor
Oil cooler (thermostat optional)
Idler gears
Bypass filter
Oil pump
Full flow filter
Full flow filter bypass valve
High pressure relief valve
Pressure regulator valve

Courtesy of Cummins Engine Company, Inc.

Objective 3

Functions of lubrication system components

a. **Bypass valve**—Diverts oil flow around the oil filter and/or oil cooler when system pressure rises above a set point due to cold, thick oil, or a clogged component

b. **Differential pressure valve**—Senses pressure drop between the filter inlet and outlet; when the difference reaches a certain level, the valve allows oil to bypass the dirty filter

c. **High pressure relief valve**—Diverts some of the oil from the oil pump directly back to the oil pan when system pressure rises above a set point

d. **Oil cooler**—Heat exchanger that transfers heat from the oil to either ambient air or engine coolant

e. **Oil galleries**—Passageways cast in the block that supply oil to the crankshaft main bearings, camshaft bearings, oil cooler, oil filter, cam followers, and rocker arms

f. **Oil pump**—Pulls oil from the oil pan, pressurizes it, and sends it to the oil filter, oil cooler, and main supply galleries

g. **Pressure regulator valve**—Spring-loaded valve that limits the maximum system operating pressure

h. **Thermostat**—Automatic device for regulating temperature; diverts cold, thick oil past the oil cooler

Objective 4

Basic types of oil filters and their operation

a. **Full flow**

- All engine oil travels directly from the pump to the filter, before being sent to the oil galleries.
- A relief valve in the filter canister allows the filter element to unseat from its base if internal pressure gets too high; unfiltered oil then flows directly out of the canister, preventing bursting.
- A differential pressure valve bridges the inlet and outlet lines running to the filter, allowing oil to completely bypass a clogged filter.
- Both the filter relief valve and the differential pressure valve act as system safeguards, ensuring adequate lubrication at all times. (Dirty oil is better than no oil.)

b. **Bypass**

- Unfiltered oil travels directly from the pump to the oil galleries.
- Approximately 10% of the oil is diverted to the oil filter.
- After filtering, the oil flows back to the crankcase.

c. **Combination full flow/bypass**

- Uses both a full flow filter and a bypass filter.
- The bypass filter extends the life of the full flow filter.
- System filtering capacity is increased.

d. **Centrifugal bypass (spinner)**

- Ten percent of the unfiltered oil is bypassed to the prefilter (similar to the bypass filter).
- Unfiltered oil enters the main cavity of the prefilter, which is spinning at about 4,000 rpm.
- Centrifugal force settles out the sludge and sediment.
- Filtered oil leaves the cavity through jets (maintaining the rotating speed) and flows back to the crankcase.

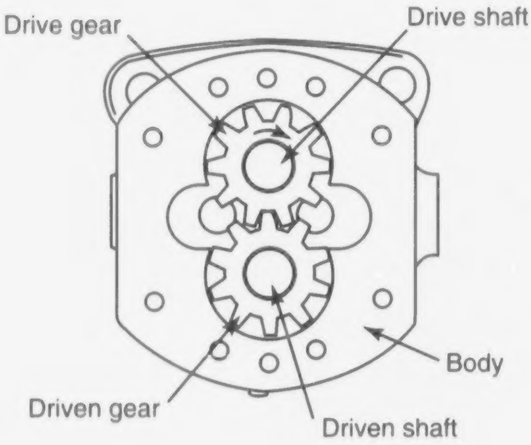
Objective 5

Basic oil pump designs and their operation

a. Gear type

- Oil is pulled into the pump and pressurized by the rotation of the gears.
- The oil stream is carried by the gear teeth around to the outlet side of the pump.
- Intermeshing teeth prevent backflow through the pump and loss of pressure.

Figure 2

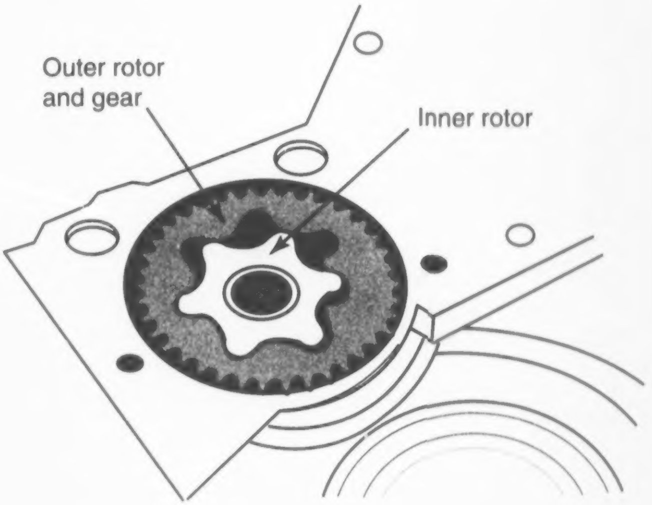


Courtesy of Detroit Diesel Corporation

b. Rotor type

- Offset rotation of the inner rotor pulls oil into the pump.
- Oil is carried through the pump in the spaces between the inner rotor and the outer rotor ring.
- At the outlet side of the pump, the spaces between the rotor and rotor ring are smaller, pressurizing the oil and forcing it out of the pump.
- Intermeshing rotor lobes prevent backflow through the pump.
- Rotor may be driven by internal or external rotor or in combination with gears.

Figure 3

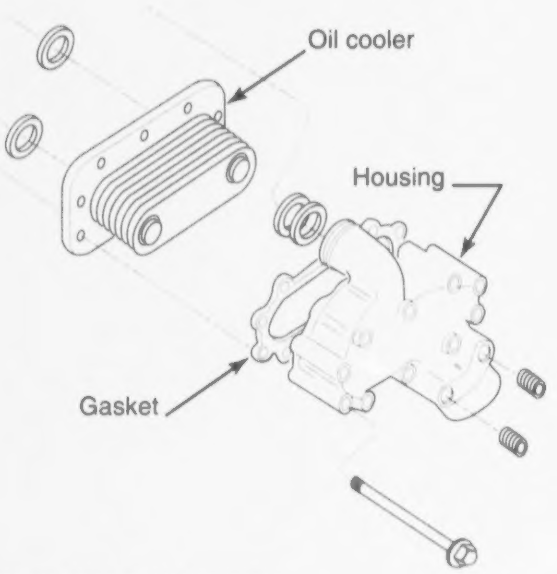


Objective 6

Basic oil cooler designs

a. Plate type

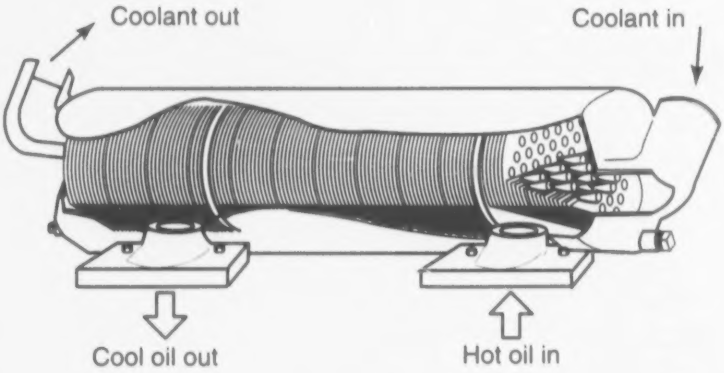
Figure 4


Oil cooler
Housing
Gasket

Courtesy of Detroit Diesel Corporation

b. Bundle type

Figure 5


Coolant out
Coolant in
Cool oil out
Hot oil in

Courtesy of Cummins Engine Company, Inc.

Objective 7

Basic oil cooler operation

a. Plate type

- Mounted on the outside of the cylinder block
- Oil flows through a series of flat plates, releasing heat to the plates.
- Coolant flows around the plates, absorbing the heat and transferring it to the radiator.

b. Bundle type

- Mounted on the outside of the cylinder block
- Oil flows around the tubes.
- Coolant flows through the tubes, absorbing the heat and transferring it to the radiator.

Objective 8

Sources of oil contamination

a. Dirt/dust in containers used to transfer lubricants from storage to engine

b. Water/condensation in storage container(s)

c. Airborne dust ingested by engine

d. Improper engine warm-up

e. Coolant leakage into crankcase

f. Oxidation

g. Carbon particles

h. Engine wear

i. Fuel dilution

Objective 9

Lubrication system monitor operation

a. Oil pressure indicator

- Oil pressure sensor responds to oil pressure changes by varying the resistance in the circuit.
- Oil pressure gauge reading varies as the resistance changes. High oil pressure causes high current flow, which causes a high reading on the gauge.

b. Oil pressure alarm (Switchgage™)

- If oil pressure falls off, the sensor sends a low reading to the Switchgage™.
- As the Switchgage™ indicator needle drops, it passes a preselected low pressure limit, triggering a magnetic switch inside the gauge.
- The switch energizes a relay, closing the fuel shutoff valve.
- Fuel flow to the injector pump stops, and so does the engine.

c. Oil temperature indicator

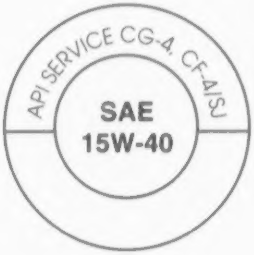
- Oil temperature sensor responds to oil temperature changes by varying the resistance in the circuit.
- Oil temperature gauge reading varies as the resistance changes. High oil temperature causes high current flow, which causes a high reading on the gauge.
- Coolant flows through the tubes, absorbing the heat and transferring it to the radiator.

Objective 10

API use codes

a. API symbol

Figure 6



b. API format

- Letters are used to classify appropriate use.
- First alpha character designates engine type. S=gasoline, C=diesel.
- Second alpha character designates the level of protection offered by the oil.
- The higher the letter designation, the higher the level of protection.

c. API classifications (most commonly used)

- **CF**—Provides protection from bearing corrosion and high temperature deposits in supercharged engines when using a wide quality range of fuels (Severe duty diesel)
- **CF-2/CG-2**—Used in two-stroke diesel engines requiring highly effective controls over wear and deposits (Heavy-duty trucks and buses, off-highway equipment, construction and stationary equipment)
- **CF-4/CG-4**—Used in turbocharged or supercharged heavy-duty diesel engines

Objective 11

Factors to consider when choosing an engine oil

a. Manufacturer's minimum requirements for the engine series being used

b. Typical operating environment for the engine

c. Fuel quality and grade

d. Availability of brands meeting specifications

e. Cost

Objective 12

Job Sheet 1—Service and Install Oil Pump and Oil Pump Drive Components

Name ____________________ Attempt Number ________

Date ____________________ Overall Rating ________

Evaluation Criteria	Rating
• Correct procedures identified for assigned vehicle	______
• Procedures completed correctly	______
• Proper tools used correctly	______
• Safety precautions observed	______
• Installed equipment functions correctly	______
• Serviced equipment meets specifications	______
• Clean-up and follow-up actions adequate	______

Basic Skills

Reading Writing Mathematics Critical Thinking Employability

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, Equipment, and Materials

- Technician's common hand tools
- Appropriate service manual
- Job ticket or work order—one is included or use appropriate one provided at your facility
- Safety equipment
- Gaskets, seals, o-rings
- Torque wrench
- Feeler gauges
- Parts cleaner
- Clean engine oil
- Shop towels
- Engine to be worked on
- Others—as recommended by instructor and equipment service manual

Guidelines

☐ 1. Dispose of waste oil in accordance with EPA guidelines.

☐ 2. Place all oily shop towels in approved airtight storage containers.

Procedure

☐ 1. Locate and follow the appropriate procedure in the service manual.

☐ 2. Complete the accompanying job ticket with all pertinent information.

☐ 3. Set parking brake, remove ignition key, and chock wheels.

☐ 4. Remove and drain the oil pump.

☐ 5. Disassemble and thoroughly clean all pump and pump drive components.

☐ 6. Closely inspect bushings, end plate, and tooth/rotor contact area.

☐ 7. Visually inspect all components for signs of cracking or galling. Record information about worn parts on the job ticket.

☐ 8. Lay a straight edge across the pump housing and measure rotor end clearance. Record below:

Manufacturer's recommended end clearance________________

Measured end clearance________________

☐ 9. Measure the clearance between rotors and the side of the pump housing. Record below:

Manufacturer's recommended rotor clearance________________

Measured rotor clearance________________

☐ 10. Lubricate the components with clean engine oil and reassemble the pump.

☐ 11. Bench test the pump assembly.

☐ 12. Reinstall the pump according to service manual, taking care to correctly mount any shims or spacers that may be needed.

☐ 13. Add oil as needed.

☐ 14. Start the engine and verify correct operation; check for leaks.

☐ 15. When you have completed your work, have your instructor verify your work and initial this sheet.

Instructor's initials________________

☐ 16. Turn in job ticket when finished.

☐ 17. Clean work area and return tools and materials to proper storage.

Evaluator's Comments: ________________________________

____

____

Job Sheet 1

PARTS LIST

QTY.	PARTS/MATERIALS	PRICE	
TOTAL PARTS/MATERIALS			

SPECIFICATIONS CHECKED

School/Work Name ______________________

Address ______________________

Phone # ______________________

Date In ____________

Date Out ____________

JOB TICKET

Customer Name ______________________

Customer Address ______________________

Customer Phone # ______________________

Vehicle/Equip.	Make & Model	License #/Motor #/Serial #	Speedometer

Condition reported by customer/service requested: ______________________

____

Services/repairs made: ______________________

____

____

____

____

____

____

____

____

____

____

____

LABOR	

Customer Authorization

I, the undersigned, have reviewed the required service and parts estimates and authorize this maintenance to be performed with the understanding that I will be notified prior to the performance of any work that significantly exceeds those estimates in time or cost.

______________________ Date ____________

Technician ____________

Supervisor ____________

Objective 13

Job Sheet 2—Service and Inspect Lubrication System Screens and Pipes

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Correct procedures identified for assigned vehicle	______
• Procedures completed correctly	______
• Proper tools used correctly	______
• Safety precautions observed	______
• Installed equipment functions correctly	______
• Serviced equipment meets specifications	______
• Clean-up and follow-up actions adequate	______

Basic Skills

Reading Writing Critical Thinking Employability

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, Equipment, and Materials

- Technician's common hand tools
- Appropriate service manual
- Job ticket or work order—one is included or use appropriate one provided at your facility
- Safety equipment
- Gaskets, seals, o-rings
- Torque wrench
- Clean engine oil
- Shop towels
- Engine to be worked on
- Others—as recommended by instructor and equipment service manual

Guidelines

☐ 1. Dispose of waste oil in accordance with EPA guidelines.

☐ 2. Place all oily shop towels in approved airtight storage containers.

Procedure

☐ 1. Locate and follow the appropriate procedure in the service manual.

☐ 2. Complete the accompanying job ticket with all pertinent information.

☐ 3. Set parking brake, remove ignition key, and chock wheels.

☐ 4. Drain oil as required.

☐ 5. Remove components as needed to gain access to screens/pipes.

☐ 6. After thoroughly cleaning, visually inspect for cracks or warped mounting surfaces. Note any damage on the job sheet.

☐ 7. During reassembly, lightly coat the new o-rings with clean engine oil.

☐ 8. Top up the crankcase as required.

☐ 9. Run the engine and check for oil leaks and/or suction leaks.

Note: Suction leaks are indicated by fluctuating oil pressure or checks that show oil pressure decreases as engine speed increases.

☐ 10. When you have completed your work, have your instructor verify your work and initial this sheet.

Instructor's initials__________________

☐ 11. Turn in job ticket when finished.

☐ 12. Clean work area and return tools and materials to proper storage.

Evaluator's Comments: ____

____

____

PARTS LIST

QTY.	PARTS/MATERIALS	PRICE	
TOTAL PARTS/MATERIALS			

SPECIFICATIONS CHECKED

School/Work Name ______________________________

Address ______________________________

Phone # ______________________________

Date In ______________

Date Out ______________

JOB TICKET

Customer Name ______________________________

Customer Address ______________________________

Customer Phone # ______________________________

Vehicle/Equip.	Make & Model	License #/Motor #/Serial #	Speedometer

Condition reported by customer/service requested: ______________________________

Services/repairs made: ______________________________

____

____

____

____

____

____

____

____

____

____

____

LABOR	

Customer Authorization

I, the undersigned, have reviewed the required service and parts estimates and authorize this maintenance to be performed with the understanding that I will be notified prior to the performance of any work that significantly exceeds those estimates in time or cost.

______________________________ Date ______________

Technician ______________

Supervisor ______________

Objective 14

Job Sheet 3—Service and Inspect Oil Pressure Regulator Valve and Bypass Valve

Name ____________________ Attempt Number ________

Date ____________________ Overall Rating ________

Evaluation Criteria	Rating
• Correct procedures identified for assigned vehicle	______
• Procedures completed correctly	______
• Proper tools used correctly	______
• Safety precautions observed	______
• Installed equipment functions correctly	______
• Serviced equipment meets specifications	______
• Clean-up and follow-up actions adequate	______

Basic Skills

Reading Writing Critical Thinking Employability

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, Equipment, and Materials

- Technician's common hand tools
- Appropriate service manual
- Job ticket or work order—one is included or use appropriate one provided at your facility
- Safety equipment
- Gaskets, seals, o-rings
- Torque wrench
- Clean engine oil
- Shop towels
- Engine to be worked on
- Others—as recommended by instructor and equipment service manual

Guidelines

☐ 1. Dispose of waste oil in accordance with EPA guidelines.

☐ 2. Place all oily shop towels in approved airtight storage containers.

Procedure

☐ 1. Locate and follow the appropriate procedure in the service manual.

☐ 2. Complete the accompanying job ticket with all pertinent information.

☐ 3. Set parking brake, remove ignition key, and chock wheels.

☐ 4. If required, drain the oil and remove the oil pan.

☐ 5. Remove the valves.

☐ 6. Visually inspect the valve and valve body for scoring or pitting. Note any problems on the job ticket.

☐ 7. Check to make sure that the valve moves easily in its bore.

☐ 8. Check the spring for proper height and pressure.

☐ 9. Lightly oil the valve and spring and reassemble.

☐ 10. Install the valve assembly.

☐ 11. Reinstall any other parts that were removed for access.

☐ 12. Refill/top up the crankcase as needed.

☐ 13. Run the engine and verify correct operation.

☐ 14. When you have completed your work, have your instructor verify your work and initial this sheet.

Instructor's initials__________________

☐ 15. Turn in job ticket when finished.

☐ 16. Clean work area and return tools and materials to proper storage.

Evaluator's Comments: ____

____

____

582

Job Sheet 3

PARTS LIST

QTY.	PARTS/MATERIALS	PRICE	
TOTAL PARTS/MATERIALS			

SPECIFICATIONS CHECKED

School/Work Name ______________________

Address ______________________

Phone # ______________________

Date In ____________

Date Out ____________

JOB TICKET

Customer Name ______________________

Customer Address ______________________

Customer Phone # ______________________

Vehicle/Equip.	Make & Model	License #/Motor #/Serial #	Speedometer

Condition reported by customer/service requested: ______________________

Services/repairs made: ______________________

LABOR	

Customer Authorization

I, the undersigned, have reviewed the required service and parts estimates and authorize this maintenance to be performed with the understanding that I will be notified prior to the performance of any work that significantly exceeds those estimates in time or cost.

______________________ Date ____________

Technician ____________

Supervisor ____________

Objective 15

Job Sheet 4—Service and Inspect Oil Cooler and Lines

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Correct procedures identified for assigned vehicle	______
• Procedures completed correctly	______
• Proper tools used correctly	______
• Safety precautions observed	______
• Installed equipment functions correctly	______
• Serviced equipment meets specifications	______
• Clean-up and follow-up actions adequate	______

Basic Skills

Reading Writing Critical Thinking Employability

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, Equipment, and Materials

- Technician's common hand tools
- Appropriate service manual
- Job ticket or work order—one is included or use appropriate one provided at your facility
- Safety equipment
- Gaskets, seals, o-rings
- Torque wrench
- Compressed air, air hose, and adapters
- Clean engine oil
- Shop towels
- Engine to be worked on
- Others—as recommended by instructor and equipment service manual

Guidelines

☐ 1. Dispose of waste oil in accordance with EPA guidelines.

☐ 2. Place all oily shop towels in approved airtight storage containers.

Procedure

☐ 1. Locate and follow the appropriate procedure in the service manual.

☐ 2. Complete the accompanying job ticket with all pertinent information.

☐ 3. Set parking brake, remove ignition key, and chock wheels.

☐ 4. Drain the cooling system.

☐ 5. Remove the oil cooler.

☐ 6. Clean the core and associated components with recommended solvent solutions. If major engine failure has occurred, replace the core.

☐ 7. Carefully remove all gasket materials from mating surfaces.

☐ 8. Pressure test the core. Record any leakage on the job sheet. Leaking cores are usually replaced with new/reconditioned units.

☐ 9. Make sure all solvent has been removed; then dry the unit with compressed air.

☐ 10. Reinstall using new o-rings and/or gaskets.

☐ 11. Top up coolant as required.

☐ 12. Start the engine and verify correct operation.

☐ 13. When you have completed your work, have your instructor verify your work and initial this sheet.

Instructor's initials__________________

☐ 14. Turn in job ticket when finished.

☐ 15. Clean work area and return tools and materials to proper storage.

Evaluator's Comments: ____

____

____

PARTS LIST

QTY.	PARTS/MATERIALS	PRICE	
TOTAL PARTS/MATERIALS			

SPECIFICATIONS CHECKED

School/Work Name ______________________

Address ______________________

Phone # ______________________

Date In ______________

Date Out ______________

JOB TICKET

Customer Name ______________________

Customer Address ______________________

Customer Phone # ______________________

Vehicle/Equip.	Make & Model	License #/Motor #/Serial #	Speedometer

Condition reported by customer/service requested: ______________________

Services/repairs made: ______________________

LABOR	

Customer Authorization

I, the undersigned, have reviewed the required service and parts estimates and authorize this maintenance to be performed with the understanding that I will be notified prior to the performance of any work that significantly exceeds those estimates in time or cost.

______________________ Date ______________

Technician ______________

Supervisor ______________

Job Sheet 4

Unit Contents

Student Components

Student Page

Objective Sheet 2B-3

Information Sheet 2B-5

Job Sheets

1—Flush, Refill, and Bleed Coolant System 2B-15
2—Inspect Water Pump, Belts, and Hoses 2B-19
3—Check Operation of Fan Assembly and Controls 2B-23
4—Test Operation of Thermostat Installed in Engine 2B-27
5—Test Operation of Thermostat on the Bench 2B-31
6—Check Operation and Accuracy of Temperature
Indicating System 2B-35

Objective Sheet

Unit Objective

After completing this unit, the student should be able to identify, inspect, and service different types of cooling systems. The student should be able to make decisions concerning the best type of coolant to use for given conditions and equipment. The student should demonstrate these competencies by completing the job sheets and by scoring a minimum of 85 percent on the written test.

Specific Objectives

After completing this unit, the student should be able to:

1. Match terms related to cooling systems with their definitions.
2. Identify common types of cooling systems.
3. Match cooling system components for an air-cooled engine with their functions.
4. Match cooling system components for a liquid-cooled engine with their functions.
5. Distinguish between the operation of air-cooled and liquid-cooled engines.
6. Describe the effects of incorrect temperature regulation.
7. Identify common types of radiators.
8. List types of drives for water pumps.
9. Identify the parts of a water pump.
10. Identify types of drive belts.
11. Match coolant items with their functions.
12. Distinguish between types of antifreeze.
13. Select from a list the characteristics of a suitable antifreeze.
14. List purposes of a radiator cap.
15. Complete statements concerning typical radiator cap operation.
16. Flush, refill, and bleed coolant system. (Job Sheet 1)
17. Inspect water pump, belts, and hoses. (Job Sheet 2)
18. Check operation of fan assembly and controls. (Job Sheet 3)
19. Test operation of thermostat installed in engine. (Job Sheet 4)

Objective Sheet

20. Test operation of thermostat on the bench. (Job Sheet 5)

21. Check operation and accuracy of temperature indicating system. (Job Sheet 6)

Information Sheet

Objective 1

Terms and definitions

a. **Antifreeze**—Material added to coolant to prevent freezing

b. **Bypass**—Design that routes coolant around the closest thermostat and directly back to the water pump inlet

c. **Cavitation erosion**—Pitting caused by vapor bubbles

d. **Coolant**—Antifreeze/water mixture circulating in the engine cooling system

e. **Deaeration circuit (vent line)**—Connects thermostat housing or water manifold to the surge tank; prevents cavitation by allowing bubbles and small amounts of trapped air to escape

f. **Dropout**—Sludge or deposits that form in or on cooling system components; caused by excessive amounts of chemicals in the engine coolant

g. **Ethylene glycol**—Chemical compound that is commonly used as an antifreeze

h. **Fill line**—Connects water pump to upper radiator tank; prevents cavitation by maintaining positive pressure inside the pump

i. **Inhibitor**—Chemical additive in antifreeze that prevents rust and pitting

j. **Manual bleeds**—Can be opened during system fill to allow trapped air to escape

k. **Permanent antifreeze**—Liquid solution that contains properties that will not readily boil away

Note: Permanent does not mean the solution never has to be tested or replaced.

l. **Water jacket**—Part of the casting that surrounds the cylinder head and engine block; contains the coolant as it passes over the cylinder liners and combustion chamber

m. **Water manifold**—Tube connecting different parts of the water jacket

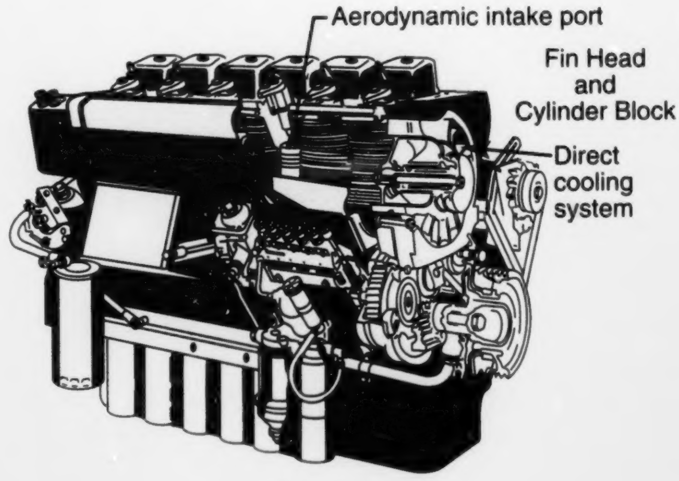
Information Sheet

Objective 2

Common types of cooling systems

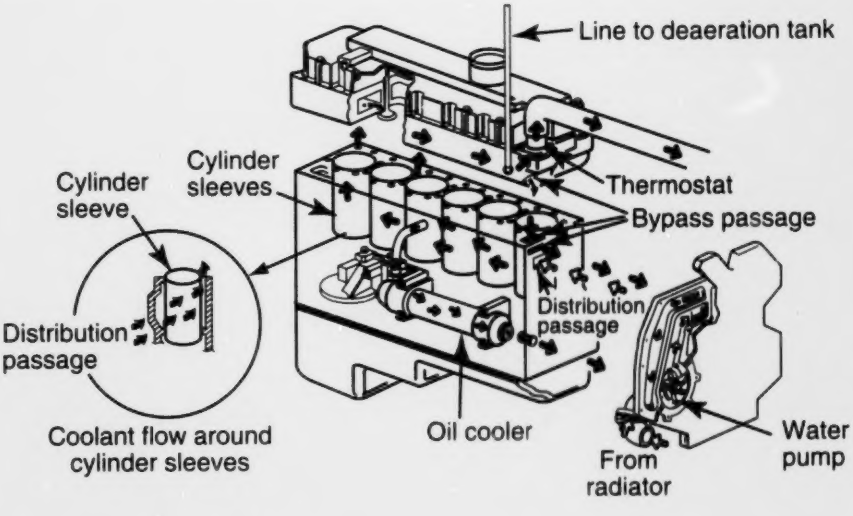
a. Air

Figure 1


Aerodynamic intake port
Fin Head and Cylinder Block
Direct cooling system

b. Liquid

Figure 2


Line to deaeration tank
Cylinder sleeves
Cylinder sleeve
Thermostat
Bypass passage
Distribution passage
Distribution passage
Coolant flow around cylinder sleeves
Oil cooler
From radiator
Water pump

Courtesy of Cummins Engine Company, Inc.

593

Objective 3

Typical cooling system components for air-cooled engines

a. **Fan**—Provides a steady supply of ambient temperature air for engine cooling

b. **Shroud**—Sheet metal cover that contains and guides the cooling air around the engine cylinders and cylinder head(s)

c. **Cooling fins**—Absorb combustion and friction heat from the engine cylinders and cylinder head(s) and dissipate it into the airstream

d. **Thermostat**—Controls the amount of air flowing from the fan; speeds engine warm-up and maintains a safe operating temperature

Objective 4

Typical cooling system components for liquid-cooled engines

a. **Radiator**—Heat exchanger that absorbs heat from the engine coolant and transfers it to the atmosphere

b. **Expansion tank**—Separate tank that collects and holds the expanding coolant; as the engine cools, the coolant is drawn back into the radiator

c. **Radiator pressure cap**—Allows the cooling system to operate under pressure; raises the effective boiling point of the coolant and prevents coolant loss from boil-over

d. **Coolant**—Mixture of antifreeze and water that absorbs engine heat

e. **Fan**—Forces air through the radiator core to speed heat transfer

f. **Fan belts**—Transmit engine motion to drive the fan and water pump

g. **Water pump**—Circulates coolant through the radiator and water jacket

h. **Thermostat**—Device that maintains stable engine operating temperature by controlling coolant flow through the engine

i. **Hoses**—Flexible connections between the engine and other parts of the cooling system

j. **Coolant filter** (optional)—Traps and collects impurities, sand, and scale; sometimes contains a water conditioner cartridge to soften the water in the cooling system

Objective 5

Cooling system operation

a. **Air-cooled engines**

- Ambient temperature air is drawn in by cooling fan and forced through sheet metal shrouding.
- The shrouds direct the air over the finned surfaces of the cylinders and cylinder heads, collecting heat.

- The heated air is expelled into the atmosphere.
- During engine warm-up, cooling air is either restricted or rerouted until engine operating temperature is reached.

b. **Liquid-cooled engines**

- The water pump circulates coolant from the radiator to the water jacket surrounding the engine block and heads.
- Engine heat passes through the cylinder walls into the water jacket, where it is absorbed by the moving coolant.
- Coolant is also routed through the oil cooler (and on some engines the air charge aftercooler).
- The heated coolant then flows past the thermostat and into the radiator.
- In the radiator, the coolant is routed through wide, thin tubes. The heat from the coolant is absorbed by the metal tubes.
- Forced air from the radiator fan removes the heat from the tubes and directs it to the atmosphere.
- During engine warm-up, the thermostat routes the coolant through a bypass loop and back to the engine. Because the coolant "bypasses" the radiator, engine operating temperature is quickly achieved.

Objective 6

Effects of incorrect temperature regulation

a. **Too hot**—Lubricating film on moving parts becomes too thin to coat and protect

- Insufficient clearance between moving parts
- Accelerated wear on bearing surface
- Scoring and seizure of pistons, rings, and valve stems
- Power loss

b. **Too cold**—Poor oil flow and poor fuel atomization

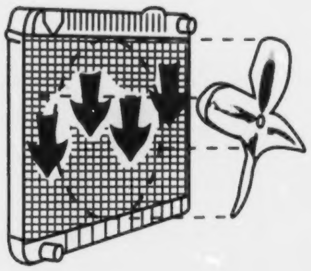
- Accelerated wear on bearing surfaces and cylinder walls
- Oil contamination
- Sludge build-up in the crankcase
- Poor fuel economy
- Power loss

Objective 7

Common types of radiators

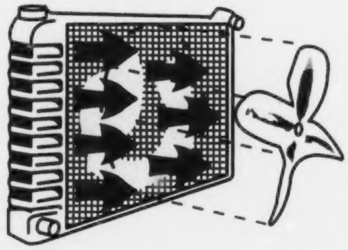
a. Down-flow

Figure 3



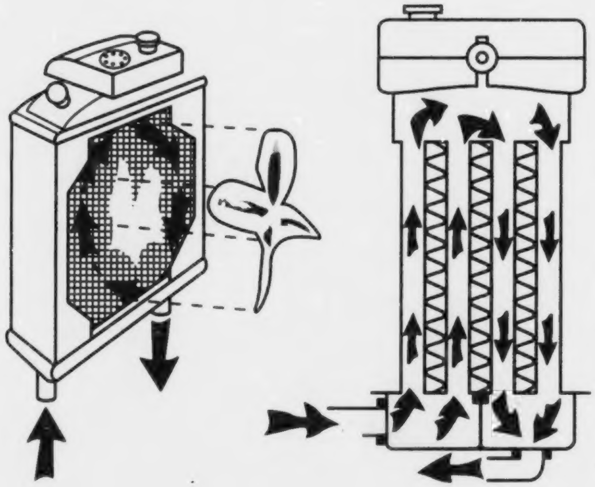
b. Cross-flow

Figure 4



c. Low-flow coolant (double bypass)

Figure 5



Objective 8

Types of drives for water pumps

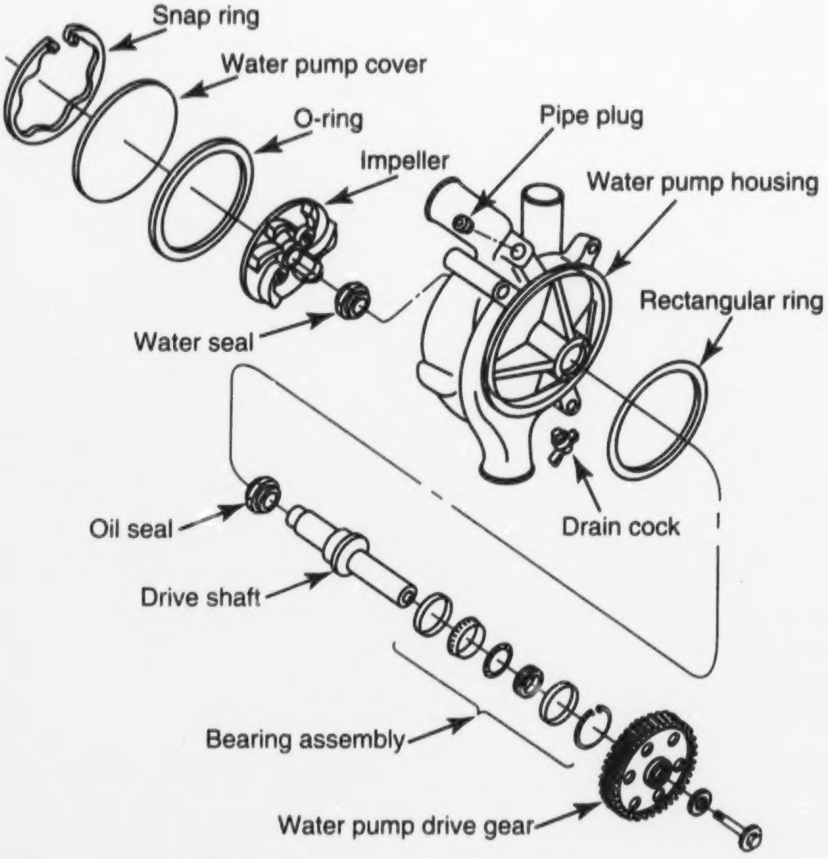
a. **Belt**—Usually mounted at the front of the engine

b. **Gear**—Driven off the gear train; may face front or rear of engine

Objective 9

Parts of a water pump

Figure 6


Snap ring
Water pump cover
O-ring
Pipe plug
Impeller
Water pump housing
Rectangular ring
Water seal
Oil seal
Drain cock
Drive shaft
Bearing assembly
Water pump drive gear

Courtesy of Detroit Diesel Corporation

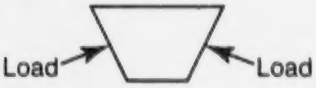
Objective 10

Types of drive belts

a. V-belt

- V-shaped belt with load applied to both angled smooth surfaces
- Commonly used in combination, matched sets, or pairs
- Commonly available $^{3}/_{8}''$–$^{1}/_{2}''$ wide

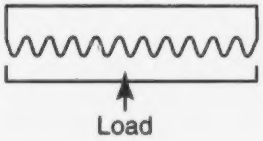
Figure 7



b. Poly V (serpentine)

- Flat belt with serpentine ridged surface on one side that receives the load and smooth surface on other side that receives no load.
- One belt is commonly used to drive most or all accessories.
- Commonly available 1"–1 1/2" wide

Figure 8



Objective 11

Functions of coolant filters, conditioners, and additives

a. **Coolant filters**

- Trap and hold sand, scale, and rust particles
- Maintain system purity by eliminating contaminants from added coolant

b. **Coolant conditioners**

- Soften the water to minimize scale build-up
- Contain rust inhibitors that provide a protective film around metal surfaces in the cooling system
- Contain seal conditioners and pump lubricants
- Prevent cavitation and erosion

c. **Coolant additives**

- Prevent corrosion and formation of deposits
- Minimize cavitation
- Provide protection for cooling system components

Objective 12

Types of antifreeze

a. **Inhibited ethylene glycol (IEG)**
  - Typically combined with distilled/deionized water in a 50/50 mix
  - Boiling point raised to 263°F
  - Freezing point lowered to -34°F
  - Highly toxic to plants, animals, and people

b. **Inhibited propylene glycol (IPG)**
  - Typically combined with distilled/deionized water in a 50/50 mix
  - Boiling point raised to 257°F
  - Freezing point lowered to -27°F
  - Thermal efficiency similar to IEG (slightly less)
  - Considered "environmentally friendly" because it is less toxic to plants, animals, and people. Sour smell and taste discourage accidental ingestion.

Objective 13

Characteristics of a suitable antifreeze

a. Prevents the coolant mixture from freezing

b. Raises the boiling point

c. Absorbs and conducts heat readily

d. Is chemically stable

e. Inhibits rust and corrosion

f. Resists foaming

Objective 14

Purposes of a radiator cap

a. Seals the radiator
  - Prevents entry of air, which causes corrosion
  - Prolongs the useful life of antifreeze and cooling system additives

b. Allows the cooling system to operate under positive pressure
  - Raises the effective boiling point of the coolant
  - Minimizes coolant loss
  - Minimizes cavitation erosion

c. Maintains system pressure at a preset level with the use of a pressure relief valve

   - Prevents damage to radiator core and hoses
   - Maintains consistent boiling point for coolant

d. Allows overflow coolant to reenter the radiator during cool-down with the use of a vacuum valve

   - Maintains correct coolant level in the radiator
   - Eliminates air pockets

Objective 15

Typical radiator cap operation

a. Cooling system at atmospheric pressure

   - Vacuum valve is closed.
   - Pressure relief valve is closed.

b. Cooling system operating at high load/high heat

   - Vacuum valve is closed.
   - Pressure relief valve opens when system pressure exceeds cap rating; coolant is released into expansion tank

c. System cool-down

   - Vacuum valve opens allowing coolant to return from expansion tank.
   - Pressure relief valve is closed.

Objective 16

Job Sheet 1—Flush, Refill, and Bleed Coolant System

Name ____________________ Attempt Number ________

Date ____________________ Overall Rating ________

Evaluation Criteria	Rating
• Correct procedures identified for assigned vehicle	______
• Procedures completed correctly	______
• Proper tools used correctly	______
• Safety precautions observed	______
• Installed equipment functions correctly	______
• Serviced equipment meets specifications	______
• Clean-up and follow-up actions adequate	______

Basic Skills

Reading Writing Critical Thinking Employability

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, Equipment, and Materials

- Technician's common hand tools
- Appropriate service manual
- Job ticket or work order—one is included or use appropriate one provided at your facility
- Safety equipment
- Drain bucket
- OEM—approved cooling system cleaner or descaling solvent
- Water
- Coolant
- Engine to be worked on
- Others—as recommended by instructor and equipment service manual

Guidelines

- Ensure that engine is stopped before beginning this procedure.
- Relieve system pressure before removing radiator cap.
- Clean up any spilled antifreeze solution—it makes metal and concrete surfaces very slippery.

Procedure

☐ 1. Locate and follow the appropriate procedure in the service manual.

☐ 2. Complete the accompanying job ticket with all pertinent information.

☐ 3. Set parking brake, remove ignition key, and chock wheels.

☐ 4. Drain the cooling system (radiator, block, intercooler/oil cooler).

☐ 5. Refill the system with water and the correct amount of cooling system cleaner.

☐ 6. Bleed air from system if required by manufacturer. Follow instructions in service manual.

☐ 7. Run engine to operating temperature. Be sure the thermostat has opened and the cleaner is circulating through the block and radiator.

☐ 8. Stop the engine and relieve cooling system pressure. Drain the system (see step #4).

☐ 9. Refill the radiator with fresh water (and neutralizer if required). Repeat steps #7 and #8.

☐ 10. Remove the radiator inlet and outlet hoses. Attach a drain hose to the top of the radiator.

☐ 11. Attach a second hose to the bottom of the radiator, and insert a flushing gun.

☐ 12. Fill the radiator with clean water, then turn on the air in short blasts. Allow the radiator to refill between blasts.

☐ 13. Continue flushing until only clean water comes out of the radiator.

☐ 14. Remove the flushing gun and drain hose. Reconnect the inlet and outlet hoses.

☐ 15. Refill the system with the correct amount of distilled water and coolant. If a supplemental coolant additive is required by the engine manufacturer, add it now.

☐ 16. Run the engine to operating temperature, then allow it to run for an additional five minutes. During this time, place it under load and check for leaks and proper temperature range.

☐ 17. Shut the engine off, allow the system to cool, and check for correct coolant level. Top up as needed.

☐ 18. Turn in job ticket when finished.

☐ 19. Clean work area and return tools and materials to proper storage.

Evaluator's Comments: ____

____

____

Job Sheet 1

PARTS LIST

QTY.	PARTS/MATERIALS	PRICE	
TOTAL PARTS/MATERIALS			

SPECIFICATIONS CHECKED

School/Work Name ________________

Address ________________

Phone # ________________

Date In ________

Date Out ________

JOB TICKET

Customer Name ________________

Customer Address ________________

Customer Phone # ________________

Vehicle/Equip.	Make & Model	License #/Motor #/Serial #	Speedometer

Condition reported by customer/service requested: ________________

Services/repairs made: ________________

LABOR	

Customer Authorization

I, the undersigned, have reviewed the required service and parts estimates and authorize this maintenance to be performed with the understanding that I will be notified prior to the performance of any work that significantly exceeds those estimates in time or cost.

________________ Date ________

Technician ________

Supervisor ________

Objective 17

Job Sheet 2—Inspect Water Pump, Belts, and Hoses

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Correct procedures identified for assigned vehicle	______
• Procedures completed correctly	______
• Proper tools used correctly	______
• Safety precautions observed	______
• Installed equipment functions correctly	______
• Serviced equipment meets specifications	______
• Clean-up and follow-up actions adequate	______

Basic Skills

Reading Writing Critical Thinking Employability

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, Equipment, and Materials

- Technician's common hand tools
- Appropriate service manual
- Job ticket or work order—one is included or use appropriate one provided at your facility
- Safety equipment
- Belt tension gauge
- Engine to be worked on
- Others—as recommended by instructor and equipment service manual

Guidelines

- Ensure that engine is stopped before beginning this procedure. Allow it to cool for 10-15 minutes before measuring and adjusting tension.
- When installing or adjusting accessory belts, be sure the pivot point bolt is properly tightened, as well as the adjusting slot bolt.
- Clean up any spilled antifreeze solution—it makes metal and concrete surfaces very slippery.

Procedure

☐ 1. Locate and follow the appropriate procedure in the service manual.

☐ 2. Complete the accompanying job ticket with all pertinent information.

☐ 3. Set parking brake, remove ignition key, and chock wheels.

- ☐ 4. Inspect water pump:
    - ☐ a. Check housing for signs of cracking or damage.
    - ☐ b. Check driveshaft (if visible) for signs of coolant leakage.

      Note: On pumps equipped with weep holes on the underside of the pump body, coolant stains/discoloration is acceptable—this occurs over time. A visible flow of coolant is not acceptable and indicates that pump service is needed.
- ☐ 5. Inspect belts:
    - ☐ a. Twist the belt and check for cracking, glazing, or fraying.
    - ☐ b. Check tension with the gauge and compare it to OEM specs for **used** belts.
- ☐ 6. Inspect hoses:
    - ☐ a. Check for bulges or cracks.
    - ☐ b. Squeeze the hose; it should be firm, neither soft nor hard.
    - ☐ c. Check that hose clamps are mounted squarely and tightened correctly.
- ☐ 7. Turn in job ticket when finished.
- ☐ 8. Clean work area and return tools and materials to proper storage.

Evaluator's Comments: ______________________________

____

____

PARTS LIST

QTY.	PARTS/MATERIALS	PRICE	
TOTAL PARTS/MATERIALS			

SPECIFICATIONS CHECKED

School/Work Name ________________________
Address ________________________
Phone # ________________________

Date In ____________
Date Out ____________

JOB TICKET

Customer Name ________________________
Customer Address ________________________
Customer Phone # ________________________

Vehicle/Equip.	Make & Model	License #/Motor #/Serial #	Speedometer

Condition reported by customer/service requested: ________________________

Services/repairs made: ________________________

LABOR	

Customer Authorization

I, the undersigned, have reviewed the required service and parts estimates and authorize this maintenance to be performed with the understanding that I will be notified prior to the performance of any work that significantly exceeds those estimates in time or cost.

________________________ Date ____________

Technician ____________
Supervisor ____________

Job Sheet 2

Objective 18

Job Sheet 3—Check Operation of Fan Assembly and Controls

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Correct procedures identified for assigned vehicle	______
• Procedures completed correctly	______
• Proper tools used correctly	______
• Safety precautions observed	______
• Installed equipment functions correctly	______
• Serviced equipment meets specifications	______
• Clean-up and follow-up actions adequate	______

Basic Skills

Reading Writing Critical Thinking Employability

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, Equipment, and Materials

- Technician's common hand tools
- Appropriate service manual
- Job ticket or work order—one is included or use appropriate one provided at your facility
- Safety equipment
- Digital voltohmmeter (DVOM)
- Tension gauge
- Engine to be worked on
- Others—as recommended by instructor and equipment service manual

Guidelines

- Ensure that engine is stopped before beginning this procedure.
- Relieve system pressure before removing radiator cap.
- Clean up any spilled antifreeze solution—it makes metal and concrete surfaces very slippery.

Procedure

☐ 1. Locate and follow the appropriate procedure in the service manual.

☐ 2. Complete the accompanying job ticket with all pertinent information.

☐ 3. Set parking brake, remove ignition key, and chock wheels.

☐ 4. Loosen belts that go around the fan pulley.

☐ 5. Grasp the fan hub and check for end play by trying to move the hub in and out.

☐ 6. Clean the fan blades and inspect for cracks or other damage.

☐ 7. Inspect the pulley grooves for rust, rough spots, and/or excessive wear.

☐ 8. Inspect thermostatic hub for signs of fluid leakage. Hub units are usually sealed and nonrepairable.

☐ 9. Tighten the fan belts. Check belt tension with a tension gauge.

☐ 10. Turn in job ticket when finished.

☐ 11. Clean work area and return tools and materials to proper storage.

Evaluator's Comments: ______________________________

____

____

PARTS LIST

QTY.	PARTS/MATERIALS	PRICE	
TOTAL PARTS/MATERIALS			

SPECIFICATIONS CHECKED

School/Work Name ______________________

Address ______________________

Phone # ______________________

Date In ______________

Date Out ______________

JOB TICKET

Customer Name ______________________

Customer Address ______________________

Customer Phone # ______________________

Vehicle/Equip.	Make & Model	License #/Motor #/Serial #	Speedometer

Condition reported by customer/service requested: ______________________

____

Services/repairs made: ______________________

____

____

____

____

____

____

____

____

____

____

LABOR	

Customer Authorization

I, the undersigned, have reviewed the required service and parts estimates and authorize this maintenance to be performed with the understanding that I will be notified prior to the performance of any work that significantly exceeds those estimates in time or cost.

______________________ Date ______________

Technician ______________

Supervisor ______________

Objective 19

Job Sheet 4—Test Operation of Thermostat Installed in Engine

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Correct procedures identified for assigned vehicle	_____
• Procedures completed correctly	_____
• Proper tools used correctly	_____
• Safety precautions observed	_____
• Installed equipment functions correctly	_____
• Serviced equipment meets specifications	_____
• Clean-up and follow-up actions adequate	_____

Basic Skills

Reading Writing Critical Thinking Employability

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, Equipment, and Materials

- Technician's common hand tools
- Appropriate service manual
- Job ticket or work order—one is included or use appropriate one provided at your facility
- Safety equipment
- Wax crayon
- Engine to be worked on
- Others—as recommended by instructor and equipment service manual

Guidelines

- Contain all loose hair and loose clothing. These are a safety hazard around operating engines.

- During this test, the engine will be HOT. Be careful about what you touch.

Procedure

☐ 1. Locate and follow the appropriate procedure in the service manual.

☐ 2. Complete the accompanying job ticket with all pertinent information.

☐ 3. Set parking brake, remove ignition key, and chock wheels.

☐ 4. Mark the thermostat housing with the wax crayon.

☐ 5. Start the engine and observe the mark you made. When the thermostat opens, the mark will melt.

☐ 6. Verify thermostat opening by observing coolant beginning to flow through the radiator upper tank.

☐ 7. Look at the temperature gauge on the dash. Record the temperature on your job ticket.

☐ 8. If the crayon mark has not melted after several minutes, check the upper radiator tank for coolant flow. If you observe coolant flow, the thermostat is probably stuck open. You will verify this in the next job sheet.

☐ 9. Shut off the engine.

☐ 10. Turn in job ticket when finished.

☐ 11. Clean work area and return tools and materials to proper storage.

Evaluator's Comments: ____________________

____

____

PARTS LIST

QTY.	PARTS/MATERIALS	PRICE	
TOTAL PARTS/MATERIALS			

SPECIFICATIONS CHECKED

School/Work Name ____________________

Address ____________________

Phone # ____________________

Date In __________

Date Out __________

JOB TICKET

Customer Name ____________________

Customer Address ____________________

Customer Phone # ____________________

Vehicle/Equip.	Make & Model	License #/Motor #/Serial #	Speedometer

Condition reported by customer/service requested: ____________________

Services/repairs made: ____________________

LABOR	

Customer Authorization

I, the undersigned, have reviewed the required service and parts estimates and authorize this maintenance to be performed with the understanding that I will be notified prior to the performance of any work that significantly exceeds those estimates in time or cost.

____________________ Date __________

Technician __________

Supervisor __________

Objective 20

Job Sheet 5—Test Operation of Thermostat On the Bench

Name ____________________ Attempt Number ________

Date ____________________ Overall Rating ________

Evaluation Criteria	Rating
• Correct procedures identified for assigned vehicle	______
• Procedures completed correctly	______
• Proper tools used correctly	______
• Safety precautions observed	______
• Installed equipment functions correctly	______
• Serviced equipment meets specifications	______
• Clean-up and follow-up actions adequate	______

Basic Skills

Reading Writing Critical Thinking Employability

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, Equipment, and Materials

- Technician's common hand tools
- Appropriate service manual
- Job ticket or work order—one is included or use appropriate one provided at your facility
- Safety equipment
- Drain bucket
- Coolant
- Hot plate
- Pan of water
- Thermometer
- Engine to be worked on
- Others—as recommended by instructor and equipment service manual

Guidelines

- Ensure that engine is stopped before beginning this procedure.
- Relieve system pressure before removing radiator cap.
- Clean up any spilled antifreeze solution—it makes metal and concrete surfaces very slippery.

Procedure

☐ 1. Locate and follow the appropriate procedure in the service manual.

☐ 2. Complete the accompanying job ticket with all pertinent information.

617

☐ 3. Set parking brake, remove ignition key, and chock wheels.

☐ 4. Drain the cooling system to below the level of the thermostat housing.

☐ 5. Remove the thermostat from the thermostat housing.

☐ 6. Clean the thermostat (if necessary).

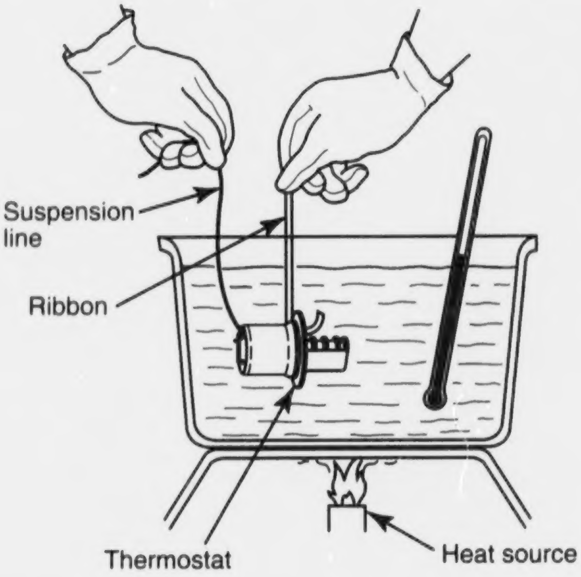
☐ 7. Visually inspect the thermostat for wear or damage.

☐ 8. Manually open the thermostat enough to insert a nylon ribbon under the thermostat seat.

☐ 9. Suspend the thermostat in a container of water so the thermostat does not touch the bottom of the container.

☐ 10. Place a thermometer also in the water, place the container on a hot plate or other source of heat, and begin to heat the water to approximately 180°F.

Figure 1



Courtesy of Navistar International Transportation Corp.

☐ 11. Observe the thermometer and record the temperature reading as soon as the thermostat drops from the nylon ribbon. This is the "start-to-open" temperature. Record below and on job ticket. Compare to manufacturer's recommended "start-to-open" temperature.

Your start-to-open reading ______________________________

Manufacturer's start-to-open recommendation ________________

☐ 12. Continue to heat the water and thermostat an additional 20° or as specified by manufacturer as the "full open" temperature, usually around 202°F.

☐ 13. Observe the thermometer and the movement of the thermostat sleeve. Observe when full-open temperature is achieved and record below and on job ticket.

Your full-open reading ______________________________

Manufacturer's full-open recommendation ________________

☐ 14. While thermostat is open, remove from water and inspect seat area for pitting and foreign deposits.

☐ 15. Determine whether or not thermostat should be replaced or reinstalled. Discuss with instructor.

- ☐ a. If thermostat does not meet recommendations, replace as approved.
- ☐ b. If thermostat meets recommendations, reinstall the thermostat using new seals/gaskets.

☐ 16. Refill the cooling system and bleed the air out (if required).

☐ 17. Run the engine and check for leaks.

☐ 18. Shut the engine off, allow the system to cool, and check for correct coolant level. Add as needed.

☐ 19. Turn in job ticket when finished.

☐ 20. Clean work area and return tools and materials to proper storage.

Evaluator's Comments: ____

____

____

Job Sheet 5

PARTS LIST

QTY.	PARTS/MATERIALS	PRICE	
TOTAL PARTS/MATERIALS			

SPECIFICATIONS CHECKED

School/Work Name ________________
Address ________________
Phone # ________________

Date In ________
Date Out ________

JOB TICKET

Customer Name ________________
Customer Address ________________
Customer Phone # ________________

Vehicle/Equip.	Make & Model	License #/Motor #/Serial #	Speedometer

Condition reported by customer/service requested: ________________

Services/repairs made:	LABOR	

Customer Authorization

I, the undersigned, have reviewed the required service and parts estimates and authorize this maintenance to be performed with the understanding that I will be notified prior to the performance of any work that significantly exceeds those estimates in time or cost.

________________ Date ________

Technician ________
Supervisor ________

Objective 21

Job Sheet 6—Check Operation and Accuracy of Temperature Indicating System

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Correct procedures identified for assigned vehicle	______
• Procedures completed correctly	______
• Proper tools used correctly	______
• Safety precautions observed	______
• Installed equipment functions correctly	______
• Serviced equipment meets specifications	______
• Clean-up and follow-up actions adequate	______

Basic Skills

Reading Writing Critical Thinking Employability

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, Equipment, and Materials

- Technician's common hand tools
- Appropriate service manual
- Job ticket or work order—one is included or use appropriate one provided at your facility
- Safety equipment
- Infrared thermometer
- Engine to be worked on
- Others—as recommended by instructor and equipment service manual

Guidelines

- Ensure that engine is stopped before beginning this procedure.
- Relieve system pressure before removing radiator cap.
- Clean up any spilled antifreeze solution—it makes metal and concrete surfaces very slippery.

Procedure

☐ 1. Locate and follow the appropriate procedure in the service manual.

☐ 2. Complete the accompanying job ticket with all pertinent information.

☐ 3. Set parking brake, remove ignition key, and chock wheels.

☐ 4. Start the engine and allow it to come up to operating temperature. (The thermostat opens and the return hose gets hot.)

☐ 5. Aim the infrared thermometer at either the water outlet manifold or the thermostat housing. Also observe the dashboard gauge reading. Record below.

Infrared thermometer reading ______________________________

Dashboard gauge reading __________________________________

☐ 6. Run the engine under load, and again note the infrared thermometer and gauge readings.

Infrared thermometer reading ______________________________

Dashboard gauge reading __________________________________

☐ 7. Record the temperature difference on your job ticket.

☐ 8. Turn in job ticket when finished.

☐ 9. Clean work area and return tools and materials to proper storage.

Evaluator's Comments: ____

____

____

PARTS LIST

QTY.	PARTS/MATERIALS	PRICE	
TOTAL PARTS/MATERIALS			

SPECIFICATIONS CHECKED

School/Work Name ____________________
Address ____________________
Phone # ____________________

Date In __________
Date Out __________

JOB TICKET

Customer Name ____________________
Customer Address ____________________
Customer Phone # ____________________

Vehicle/Equip.	Make & Model	License #/Motor #/Serial #	Speedometer

Condition reported by customer/service requested: ____________________

Services/repairs made:	LABOR	

Customer Authorization

I, the undersigned, have reviewed the required service and parts estimates and authorize this maintenance to be performed with the understanding that I will be notified prior to the performance of any work that significantly exceeds those estimates in time or cost.

____________________ Date __________

Technician __________
Supervisor __________

Unit 3-B Cylinder Blocks and Liners

Unit Contents

Student Components

Student Page

Objective Sheet 3B-3

Information Sheet 3B-5

Job Sheets

1—Pressure Test a Cylinder Block 3B-11
2—Disassemble and Clean a Cylinder Block 3B-15
3—Inspect a Cylinder Block 3B-19
4—Install New Camshaft Bushings 3B-27
5—Clean and Inspect Cylinder Bores 3B-31
6—Install Cylinder Liners and Set Liner Protrusion 3B-35

Objective Sheet

Unit Objective

After completing this unit, the student should be able to identify different cylinder block and liner designs, as well as inspect and service cylinder blocks and liners. The student should demonstrate these competencies by completing the job sheets and by scoring a minimum of 85 percent on the written test.

Specific Objectives

After completing this unit, the student should be able to:

1. Match terms related to cylinder blocks and liners with their definitions.
2. Distinguish between types of cylinder block cooling methods.
3. Identify types of cylinder liners.
4. Match types of cylinder liners with their characteristics.
5. Complete statements concerning causes of abnormal sleeve wear.
6. Pressure test a cylinder block. (Job Sheet 1)
7. Disassemble and clean a cylinder block. (Job Sheet 2)
8. Inspect a cylinder block. (Job Sheet 3)
9. Install new camshaft bushings. (Job Sheet 4)
10. Clean and inspect cylinder bores. (Job Sheet 5)
11. Install cylinder liners and set liner protrusion. (Job Sheet 6)

Information Sheet

Objective 1

Terms and definitions

a. **Counterbore**—Lip machined in the top of block bore that forms a mechanical stop for the cylinder liner

b. **Crevice seal**—Lower water jacket seal between a wet cylinder liner and the crankcase

c. **Crocus cloth**—Flexible cloth impregnated with iron oxide particles that cleans metal surfaces without removing any material

d. **Cylinder liner**—Removable sleeve inserted into the bore of an engine block and used as a load-bearing surface for the piston and rings

e. **Cylinder liner protrusion**—Distance the cylinder liner stands out (protrudes) above the block deck surface when installed

f. **Cylinder pack**—One-cylinder kit consisting of liner, piston, and rings

Objective 2

Types of cylinder block cooling methods

a. **Liquid cooled cylinder blocks**

- Cooling jacket is used which adds weight, strength, and sound absorption.
- Hot water is available for in-cab heating and defrosting.
- Cylinder operating temperatures are more even which is critical for emissions.
- Cylinder replacement is less costly.

b. **Air cooled cylinder blocks**

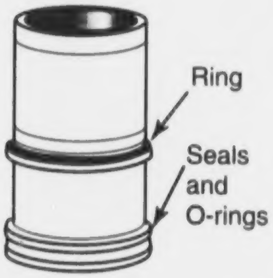
- Cooling jacket and coolant have been eliminated which reduces weight.
- Radiator, water pump, and thermostat are not used.
- Cylinders are usually integral-bore design with cooling fins.
- Engine noise is greater due to lack of sound-absorbing cooling jacket.
- Cylinders and heads must be kept clean to maximize heat transfer and to minimize contamination of hot air used for heater/defroster functions inside the vehicle.

Objective 3

Types of cylinder liners (sleeves)

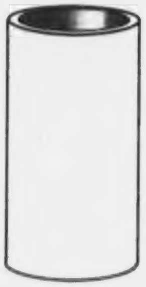
a. Wet liner/sleeve

Figure 1


Ring
Seals and O-rings

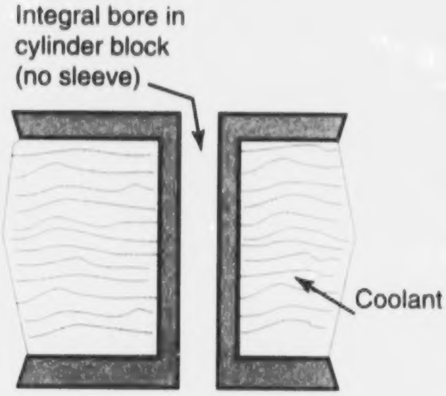
b. Dry liner/sleeve

Figure 2



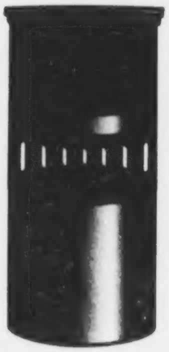
c. Integral bore (cast-in-block)

Figure 3


Integral bore in cylinder block (no sleeve)
Coolant

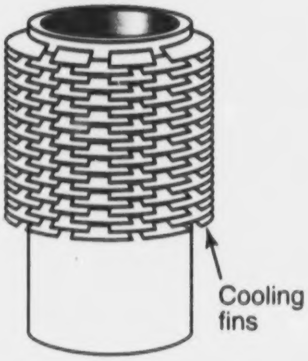
d. Combination wet/dry liner

Figure 4



e. Air-cooled sleeve

Figure 5



Objective 4

Characteristics of cylinder liners (sleeves)

a. **Wet liner/sleeve**

- Individual cylinder liners fit into machined holes in the bore deck and lower block.
- Liner provides a wear surface for the piston and rings and also forms part of the water jacket.
- Liner sealing is provided by the head gasket at the top and an o-ring at the bottom. Head gasket and o-ring must be correctly installed to prevent leakage of combustion gases and coolant.
- Advantages
  - — Coolant flows around the liner allowing direct heat transfer from the cylinder to the coolant. This results in better combustion control and greater efficiency.
  - — Block reconditioning is easily accomplished by installing cylinder packs. Removal of the block from the vehicle is not required.
  - — If required, cylinder liners can be replaced individually.
  - — The cylinder block itself remains virtually unworn.
- Disadvantages
  - — Seal placement and seating are critical during installation.
  - — The o-ring seals used at the bottom of the liner can fail and leak, contaminating the crankcase oil.

b. **Dry liner/sleeve**

- Individual cylinder liners are press-fit into machined cylinders in the cylinder block.
- The liner forms an inner bore to the existing cylinder and provides a wear surface for the piston and rings.
- Advantages
    - Block reconditioning is easily accomplished by replacing the liner/piston/ring assembly.
    - If required, cylinder liners can be replaced individually.
    - Because the liner is not an integral part of the water jacket, there are no seals. Installation is simplified, and potential seal failure and leakage are eliminated.
- Disadvantages
    - Coolant does not flow directly around the liner.
    - Heat transfer does not occur as quickly as in the wet liner block.

c. **Integral bore (cast-in-block)**

- Piston and rings ride directly in the block; there is no sleeve.
- Typically used in light-duty automotive applications and small-displacement farm/industrial motors.
- Advantages
    - Eliminates the expense of parts and labor associated with liner replacement.
    - Eliminates the problem of o-ring seal failure and crankcase oil contamination.
- Disadvantages
    - Cylinder repair requires removal of the block from the vehicle.
    - Individual cylinder bores cannot be repaired without disassembling the engine.
    - Once the overbore limit is reached, the block must either be sleeved or replaced.

d. **Combination wet/dry liner**

- The upper half of the liner is directly cooled by liquid surrounding the liner.
- At the air inlet ports, the liner is cooled by the air introduced into the cylinder through equally spaced ports around the liner.
- The lower half of the liner is cooled by water inside the cylinder block water jacket surrounding the liner.
- Two seal rings, recessed in cylinder bore, are used between liner and block to prevent water leakage.
- Advantage—Cooling capacity is increased.
- Disadvantage—Coolant leaks and water into intake ports are possibilities. Seals must be properly maintained.

e. **Air-cooled sleeve**

- Top portion is covered with cooling fins that are exposed to air blown by the fan.
- Bottom portion is smooth and fits in cylinder block. This portion is surrounded by lubricant so it is cooled by the lubrication system.
- Advantage—Fewer moving parts result in less weight and fewer problems.
- Disadvantage—Harder to cool in high heat environments

Objective 5

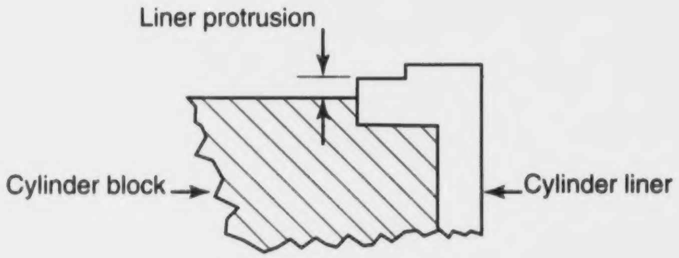
Cause of abnormal sleeve wear

a. **Twisted o-ring seals**

- O-ring does not seat correctly and causes out-of-round condition in the liner. This causes the liner to bulge slightly, exerting excess pressure against the piston and rings.
- Both liner and rings wear rapidly causing compression leakage, increased oil consumption, and blow-by.

b. **Incorrect liner protrusion**

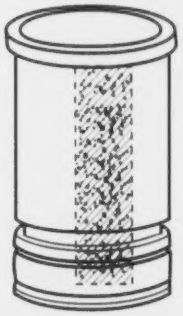
Figure 6



- Liner protrusion creates a weak head gasket seal at either that liner or an adjacent one.
- The head gasket seal quickly fails allowing compression gas leakage into the cooling system during engine operation and coolant seepage into the cylinder when the engine sits idle.
- Compression gas in the cooling system forces coolant out of the system causing engine overheating.
- Coolant seepage into the cylinder can cause hydraulic lock on startup destroying the piston and connecting rod.

c. **Cavitation erosion**

Figure 7



- Cavitation erosion occurs when air bubbles in the coolant flow strike the cylinder liner removing small bits of liner material.
- This condition is caused by the depletion of supplemental coolant additives (SCAs).
- If left uncorrected, the liner will eventually fail causing lubrication system and cooling system contamination.

Objective 6

Job Sheet 1—Pressure Test a Cylinder Block

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	**Rating**
• Engine service manual used correctly	______
• Tools and precision measuring equipment used correctly	______
• Shop safety procedures followed	______
• Work area clean and well organized	______
• Job ticket completed correctly	______

Basic Skills

Reading Writing Critical Thinking Employability

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, Equipment, and Materials

- Technician's common hand tools
- Appropriate service manual
- Job ticket or work order—one is included or use appropriate one provided at your facility
- Safety equipment
- Compressed air
- Block test strips
- Water and antifreeze mix (50/50)
- Cylinder block to be worked on
- Others—as recommended by instructor and equipment service manual

Guidelines

- Because the cylinder block supports all other engine components, it is critical that the block be mechanically and structurally sound. The first inspection that you will perform will identify any defects that would potentially render the block useless for further service. Knowing this before any reconditioning operations are started will save you a great deal of time and effort.

- Although there are several different ways to check a cylinder block for cracks, pressure testing is the preferred method. There are two specific advantages:

  — It is equally effective on cast iron, steel, aluminum, and aluminum-alloys.

  — It is inexpensive and easily performed.

Job Sheet 1

Procedure

☐ 1. Locate and follow the appropriate procedure in the service manual.

☐ 2. Complete the accompanying job ticket with all pertinent information.

☐ 3. Prepare the cylinder block.

  ☐ a. If the cylinder block uses removable sleeves, ensure that they are sealed top and bottom. (Some manufacturers recommend installing new seal rings and crevice seals.)

  ☐ b. Install cylinder block test strips and seal the water jacket as specified by the manufacturer.

☐ 4. Fill the water jacket with a 50/50 mix of water and antifreeze.

☐ 5. Apply 20 psi air pressure to the water jacket. Maintain this pressure for two hours. This will allow sufficient time for the coolant to work its way through any cracks.

☐ 6. At the end of the test period, examine the block, upper and lower sleeve area, and crankcase for any indication of antifreeze. The presence of antifreeze indicates a crack in either the block or the water jacket.

☐ 7. Fill in the blanks below with your results. Discuss with your instructor whether or not this block is serviceable.

Engine manufacturer ______________________________

Engine model ______________________________

Leakage points ______________________________

____

☐ 8. Have instructor check your work.

☐ 9. Turn in job ticket when finished.

☐ 10. Clean work area and return tools and materials to proper storage.

Evaluator's Comments: ______________________________

____

____

PARTS LIST

QTY.	PARTS/MATERIALS	PRICE	
TOTAL PARTS/MATERIALS			

SPECIFICATIONS CHECKED

School/Work Name ____________________

Address ____________________

Phone # ____________________

Date In ____________

Date Out ____________

JOB TICKET

Customer Name ____________________

Customer Address ____________________

Customer Phone # ____________________

Vehicle/Equip.	Make & Model	License #/Motor #/Serial #	Speedometer

Condition reported by customer/service requested: ____________________

Services/repairs made: ____________________

LABOR	

Customer Authorization

I, the undersigned, have reviewed the required service and parts estimates and authorize this maintenance to be performed with the understanding that I will be notified prior to the performance of any work that significantly exceeds those estimates in time or cost.

____________________ Date ____________

Technician ____________

Supervisor ____________

Objective 7

Job Sheet 2—Disassemble and Clean a Cylinder Block

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Engine service manual used correctly	______
• Tools and precision measuring equipment used correctly	______
• Shop safety procedures followed	______
• Work area clean and well organized	______
• Job ticket completed correctly	______

Basic Skills

Reading Writing Critical Thinking Employability

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, equipment, and materials

- Technician's common hand tools
- Appropriate service manual
- Job ticket or work order—one is included or use appropriate one provided at your facility
- Safety equipment
- Steam cleaner
- Cold tank
- Cam bushing removal tool
- Liner removal tool
- Precision measuring tools as specified by the instructor
- Cylinder block to be worked on
- Others—as recommended by instructor and equipment service manual

Caution: You will be working with compressed air, high pressure steam, abrasives, caustic chemical solutions, and heavy parts. Wear eye protection, gloves, and other protective clothing as specified by your instructor. Follow all shop safety procedures.

Procedure

☐ 1. Locate and follow the appropriate procedure in the service manual.

☐ 2. Complete the accompanying job ticket with all pertinent information.

Note: Your engine service manual will list the specific procedures needed for the engine block you are servicing. Additionally, it will give you step-by-step instructions for the procedures. The following is to be used as a general outline and does not supersede your engine service manual.

☐ 3. Remove cylinder liner and inspect.

  ☐ a. Remove cylinder liners using the step-by-step procedure outlined in your engine service manual.

  ☐ b. As you remove the liners, label them by cylinder number, and set them aside in an orderly manner. Inspect each individual liner. Additional inspection will be performed in a later job sheet.

  ☐ c. Have your instructor inspect your work and initial this section of your job sheet.

  Instructor's initials ____________________

☐ 4. Remove camshaft bushing, if applicable.

  ☐ a. Remove the camshaft bushings using the procedure outlined in your engine service manual. If you need information on tool use, consult your instructor. You can also refer to the tool manufacturer's instructions if you need further information.

  ☐ b. As you remove the bushings, place them in order in your work area.

  Note: Cam bushings must be removed before chemically cleaning the block. The bushing material will dissolve in the tank and ruin the chemical cleaners.

  ☐ c. Have your instructor inspect your work and initial this section of your job sheet.

  Instructor's initials ____________________

Caution: You will be using strong chemical cleaning solutions that are very hot. These can cause injury from both scalding and chemical burns. Wear protective clothing and follow all shop safety procedures!

☐ 5. Clean cylinder block.

  ☐ a. Consult your instructor to be sure that your cylinder block is ready to be cleaned.

  ☐ b. Follow your instructor's directions for the chemical cleaning and rinsing procedure.

> **Caution**: You will be using high pressure steam to clean off the chemical solution or neutralizer. Make sure the area is clear of other students.

  ☐ c. Use compressed air to dry the block.

  ☐ d. Then apply a thin coat of engine oil to all machined surfaces.

  ☐ e. Have your instructor inspect your work and initial this section of your job sheet.

  Instructor's initials ________________

☐ 6. Turn in job ticket when finished.

☐ 7. Clean work area and return tools and materials to proper storage.

Evaluator's Comments: ______________________________________

____

____

PARTS LIST

QTY.	PARTS/MATERIALS	PRICE	
TOTAL PARTS/MATERIALS			

SPECIFICATIONS CHECKED

School/Work Name ____________________

Address ____________________

Phone # ____________________

Date In ____________

Date Out ____________

JOB TICKET

Customer Name ____________________

Customer Address ____________________

Customer Phone # ____________________

Vehicle/Equip.	Make & Model	License #/Motor #/Serial #	Speedometer

Condition reported by customer/service requested: ____________________

Services/repairs made: ____________________

LABOR	

Customer Authorization

I, the undersigned, have reviewed the required service and parts estimates and authorize this maintenance to be performed with the understanding that I will be notified prior to the performance of any work that significantly exceeds those estimates in time or cost.

____________________ Date ____________

Technician ____________

Supervisor ____________

Objective 8

Job Sheet 3—Inspect a Cylinder Block

Name ________________ Attempt Number ________

Date ________________ Overall Rating ________

Evaluation Criteria	Rating
• Engine service manual used correctly	______
• Tools and precision measuring equipment used correctly	______
• Shop safety procedures followed	______
• Work area clean and well organized	______
• Job ticket completed correctly	______

Basic Skills

Reading Writing Critical Thinking Employability

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, Equipment, and Materials

- Technician's common hand tools
- Appropriate service manual
- Job ticket or work order—one is included or use appropriate one provided at your facility
- Safety equipment
- Straight edge
- Feeler gauge set
- Depth micrometer
- Crocus cloth
- Precision measuring tools as specified by the instructor
- Cylinder block to be worked on
- Others—as recommended by instructor and equipment service manual

Procedure

☐ 1. Locate and follow the appropriate procedure in the service manual.

☐ 2. Complete the accompanying job ticket and worksheet with all pertinent information.

☐ 3. Check the cylinder block deck for flatness.

  ☐ a. Clean the block deck to remove all carbon, corrosion, and gasket material.

  ☐ b. Check flatness end-to-end. Note the maximum clearance measured, and record your answer on the worksheet attached.

- ☐ c. Check flatness side-to-side. Note the maximum clearance measured, and record your answer on the worksheet attached.

☐ 4. Measure cam bearing bore for out-of-roundness.

- ☐ a. Measure the cam bearing bore vertically (in line with the cylinders). Record this measurement as "Diameter A" in Table 1 of the worksheet.
- ☐ b. Now measure the cam bearing bore at right angle to that measurement (perpendicular to the cylinders). Record this measurement as "Diameter B" in Table 1.
- ☐ c. Subtract the difference and write your answer in the "Bore Out-of-Round" column.

☐ 5. Measure main bearing bore for out-of-roundness.

- ☐ a. Torque main bearing caps to OEM specifications.
- ☐ b. Measure the main bearing bores. Record this information in "Diameter A" in Table 2 of the worksheet.
- ☐ c. Measure the main bearing bore again, perpendicular to first measurements. Record this information in "Diameter B" in Table 2.
- ☐ d. Subtract the difference between the two measurements and record this in the "Bore Out-of-Round" column in Table 2.

☐ 6. Check main bearing bore alignment.

- ☐ a. Lay a straightedge down the center of the main bearing saddles.
- ☐ b. Observe any air gaps between the straightedge and the block surface.
- ☐ c. Repeat this procedure holding the straightedge along the main bearing cap mating surface of the main bearing saddles. Do this for both mating surfaces.
- ☐ d. If there are no air gaps visible during these three measurements, the main bearing bores are straight and true.

- ☐ e. If air gaps are present, the main bearing bores will require alignment boring. This requires sending the block out to a machine shop.
- ☐ f. Record the results on the worksheet.

☐ 7. Measure sleeve counterbore depth and press-fit area, if applicable.

- ☐ a. Using the depth micrometer, check counterbore depth in four places for each cylinder.
- ☐ b. Compare your readings for each cylinder with the manufacturer's recommendations. Note any cylinders that fall outside these specifications.

☐ 8. Have your instructor review this job sheet as well as the accompanying worksheet, and initial in the spaces provided. Based on your findings during the block inspection procedures, your instructor will decide what, if any, machining operations need to be carried out to prepare this block for further service.

Instructor's initials ____________________

☐ 9. Turn in job ticket when finished.

☐ 10. Clean work area and return tools and materials to proper storage.

Evaluator's Comments: ____

____

____

Unit 3-B, Worksheet for Job Sheet 3

Name ______________________ Date __________ Attempt number ________

1. Cylinder block deck

   a. Deck surface clean and smooth ______________________

   b. Maximum warp end-to-end ______________________

   c. Maximum warp side-to-side ______________________

   d. Manufacturer's maximum allowable warp ______________________

2. Cam bearing bore out-of-roundness

   Table 1

Cam Bearing Bore	Diameter "A" (Parallel)	Diameter "B" (Perpendicular)	Bore Out-of-Round (Difference)
1			
2			
3			
4			
5			
6			
7			
8			

Manufacturer's maximum allowable out-of-round ______________________

Worksheet for Job Sheet 3

3. Main bearing out-of-roundness

Table 2

Main Bearing Bore	Diameter "A" (Parallel)	Diameter "B" (Perpendicular)	Bore Out-of-Round (Difference)
1			
2			
3			
4			
5			
6			
7			
8			

Manufacturer's maximum allowable out-of-round ____________________

Main bearing cap torque ____________________

4. Main bearing bore alignment

Are main bearing bores aligned? ____________________

5. Sleeve counterbore depth

Cylinder 1 ____________ Cylinder 5 ____________

Cylinder 2 ____________ Cylinder 6 ____________

Cylinder 3 ____________ Cylinder 7 ____________

Cylinder 4 ____________ Cylinder 8 ____________

Manufacturer's recommended maximum variation ____________________

Instructor's initials ____________________

PARTS LIST

QTY.	PARTS/MATERIALS	PRICE	
TOTAL PARTS/MATERIALS			

SPECIFICATIONS CHECKED

School/Work Name ______
Address ______
Phone # ______

Date In ______
Date Out ______

JOB TICKET

Customer Name ______
Customer Address ______
Customer Phone # ______

Vehicle/Equip.	Make & Model	License #/Motor #/Serial #	Speedometer

Condition reported by customer/service requested: ______

Services/repairs made: ______

	LABOR	

Customer Authorization

I, the undersigned, have reviewed the required service and parts estimates and authorize this maintenance to be performed with the understanding that I will be notified prior to the performance of any work that significantly exceeds those estimates in time or cost.

______ Date ______

Technician ______
Supervisor ______

Objective 9

Job Sheet 4—Install New Camshaft Bushings

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Engine service manual used correctly	_____
• Tools and precision measuring equipment used correctly	_____
• Shop safety procedures followed	_____
• Work area clean and well organized	_____
• Job ticket completed correctly	_____

Basic Skills

Reading Writing Critical Thinking Employability

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, Equipment, and Materials

- Technician's common hand tools
- Appropriate service manual
- Job ticket or work order—one is included or use appropriate one provided at your facility
- Safety equipment
- Cam bearing installation tool
- Felt tip pen (black)
- Camshaft and gear
- Assembly lube
- Cylinder block to be worked on
- Others—as recommended by instructor and equipment service manual

Guidelines

- Cam-in-block engines typically use a one-piece bushing to support the camshaft in the block.

- Cam-in-head (overhead cam) engines utilize either a one-piece bushing or a two-piece split bearing, similar to the main and connecting rod bearings.

  Note: Since installation of split bearings is fairly straight forward and simple, this job sheet will focus on bushing installation.

Procedure

☐ 1. Locate and follow the appropriate procedure in the service manual.

☐ 2. Complete the accompanying job ticket with all pertinent information.

☐ 3. Stage the bushings in the order that they will be installed.

☐ 4. Using the felt tip pen, draw a line across the width of each bushing through the bushing oil hole. This helps you to line up the oil hole in the bushing with the oil hole in the block.

☐ 5. Follow the instructions given in your service manual and by the tool manufacturer to carefully install the bushings.

☐ 6. After each bushing is installed, check it carefully for the following:

  ☐ a. Oil hole alignment

  ☐ b. Bearing seated squarely in the block

  ☐ c. No burrs around the edge of the bushing

☐ 7. When all bushings have been installed and checked, generously wipe assembly lube around the inside of each bushing.

☐ 8. Insert the camshaft. It should slide in easily. If it hangs up, do not force it. Either a bearing is incorrectly installed, or there is a high spot on the inside surface. Remove the camshaft and reinspect your work. If necessary, consult your service manual and perform the procedure for removing camshaft bushing high spots.

☐ 9. Once the camshaft is installed in the block, attach the camshaft gear. Grasping the gear, you should be able to turn the camshaft by hand.

☐ 10. Have your instructor check your work.

☐ 11. Turn in job ticket when finished.

☐ 12. Clean work area and return tools and materials to proper storage.

Evaluator's Comments: ______________________________

____

____

PARTS LIST

QTY.	PARTS/MATERIALS	PRICE	
TOTAL PARTS/MATERIALS			

SPECIFICATIONS CHECKED

School/Work Name ____________________
Address ____________________
Phone # ____________________

Date In ____________
Date Out ____________

JOB TICKET

Customer Name ____________________
Customer Address ____________________
Customer Phone # ____________________

Vehicle/Equip.	Make & Model	License #/Motor #/Serial #	Speedometer

Condition reported by customer/service requested: ____________________

Services/repairs made: ____________________

LABOR	

Customer Authorization

I, the undersigned, have reviewed the required service and parts estimates and authorize this maintenance to be performed with the understanding that I will be notified prior to the performance of any work that significantly exceeds those estimates in time or cost.

____________________ Date ____________

Technician ____________
Supervisor ____________

Objective 10

Job Sheet 5—Clean and Inspect Cylinder Bores

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Engine service manual used correctly	______
• Tools and precision measuring equipment used correctly	______
• Shop safety procedures followed	______
• Work area clean and well organized	______
• Job ticket completed correctly	______

Basic Skills

Reading Writing Mathematics Critical Thinking Employability

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, equipment, and materials

- Technician's common hand tools
- Appropriate service manual
- Job ticket or work order—one is included or use appropriate one provided at your facility
- Safety equipment
- Cylinder bore gauge set
- Hand drill
- Flex hone
- Compressed air
- Bore brush
- Detergent and water solution
- Cylinder block to be worked on
- Others—as recommended by instructor and equipment service manual

Procedure

☐ 1. Locate and follow the appropriate procedure in the service manual.

☐ 2. Complete the accompanying job ticket with all pertinent information.

☐ 3. Clean each cylinder bore thoroughly using detergent and hot water.

☐ 4. Dry with compressed air.

☐ 5. Lightly oil the bores to protect them.

☐ 6. Check for out-of-roundness.

  ☐ a. Measure the bore diameter at the top of the liner. Record this measurement in the "A" column of Table 1 on the worksheet.

  ☐ b. Now measure the bore diameter at right angles from your first measurement. You must measure the bore at the same height as in the step above. Record this in the "B" column of Table 1.

  ☐ c. Repeat steps "a" and "b" for the bottom of the liner bore. Record your measurements on Table 1.

  ☐ d. Repeat steps "a" through "c" for each cylinder bore. Record your measurements in the appropriate box on Table 1.

☐ 7. Check for taper.

  ☐ a. Measure the bore diameter at the top of the ring wear area. Record this measurement in the "A" column of Table 2 on the worksheet.

  ☐ b. Measure the bore diameter at the bottom of the ring wear area. Record this measurement tin the "B" column of Table 2.

  ☐ c. Subtract "B" from "A," and record the difference in the "Cylinder Taper" column.

☐ 8. Have your instructor check your work.

☐ 9. Turn in job ticket when finished.

☐ 10. Clean work area and return tools and materials to proper storage.

Evaluator's Comments: ____________________

____

____

Unit 3-B, Worksheet for Job Sheet 5

Name ______________________________ Date ___________ Attempt number ________

Table 1—Cylinder Out-of-Round

Cylinder	Diameter "A"	Diameter "B"	Cylinder Out-of-Round
1 Top			
Bottom			
2 Top			
Bottom			
3 Top			
Bottom			
4 Top			
Bottom			
5 Top			
Bottom			
6 Top			
Bottom			
7 Top			
Bottom			
8 Top			
Bottom			

Table 2—Cylinder Taper

Cylinder	Diameter "A"	Diameter "B"	Cylinder Taper
1			
2			
3			
4			
5			
6			
7			
8			

PARTS LIST

QTY.	PARTS/MATERIALS	PRICE	
TOTAL PARTS/MATERIALS			

SPECIFICATIONS CHECKED

School/Work Name ____________________

Address ____________________

Phone # ____________________

Date In __________

Date Out __________

JOB TICKET

Customer Name ____________________

Customer Address ____________________

Customer Phone # ____________________

Vehicle/Equip.	Make & Model	License #/Motor #/Serial #	Speedometer

Condition reported by customer/service requested: ____________________

Services/repairs made: ____________________

LABOR	

Customer Authorization

I, the undersigned, have reviewed the required service and parts estimates and authorize this maintenance to be performed with the understanding that I will be notified prior to the performance of any work that significantly exceeds those estimates in time or cost.

____________________ Date __________

Technician __________

Supervisor __________

657

658

Objective 11

Job Sheet 6—Install Cylinder Liners and Set Liner Protrusion

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Engine service manual used correctly	______
• Tools and precision measuring equipment used correctly	______
• Shop safety procedures followed	______
• Work area clean and well organized	______
• Job ticket completed correctly	______

Basic Skills

Reading Writing Mathematics Critical Thinking Employability

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, equipment, and materials

- Technician's common hand tools
- Appropriate service manual
- Job ticket or work order—one is included or use appropriate one provided at your facility
- Safety equipment
- Sleeve driver
- Hammer
- Straight edge
- Dial indicator
- Liner o-rings and seals
- Liner shims (as necessary)
- Seal lubricant (as recommended)
- Cylinder bore gauge
- Cylinder block to be worked on
- Others—as recommended by instructor and equipment service manual

Procedure

☐ 1. Locate and follow the appropriate procedure in the service manual.

☐ 2. Complete the accompanying job ticket with all pertinent information.

☐ 3. Install liners.

  ☐ a. Recheck block bores to be sure that they are clean and free of corrosion or scale.

  ☐ b. Following the directions in your service manual, install and lubricate the liner o-rings.

  ☐ c. Install the liners, being sure to fully seat the liner seals.

  ☐ d. If the liner does not appear to seat evenly and completely, do not force it. Remove it, and reinspect the block seal areas for foreign material and the o-rings for twisting.

☐ 4. Check for out-of-roundness.

  ☐ a. Measure the bore diameter at the top of the liner. Record this measurement in the "A" column of Table 1 on the worksheet.

  ☐ b. Now measure the bore diameter at right angles from your first measurement. You must measure the bore at the same height as in the step above. Record this in the "B" column of Table 1.

  ☐ c. Repeat steps "a" and "b" for the bottom of the liner bore. Record your measurements on Table 1.

  ☐ d. Repeat steps "a" through "c" for each cylinder bore. Record your measurements in the appropriate box on Table 1.

☐ 5. Check for taper.

  ☐ a. Measure the bore diameter at the top of the ring wear area. Record this measurement in the "A" column of Table 2 on the worksheet.

  ☐ b. Measure the bore diameter at the bottom of the ring wear area. Record this measurement in the "B" column of Table 2.

  ☐ c. Subtract "B" from "A," and record the difference in the "Cylinder Taper" column.

  Note: If the liner checked good on the bench, but is out-of-round after installation, the cause is most likely a twisted o-ring. Remove the liner, inspect the o-ring for damage (replace if necessary), and reinstall.

☐ 6. Check liner protrusion or height.

  ☐ a. After the liner is fully seated in the block, install and zero the dial indicator. Consult your service manual for this procedure.

  ☐ b. With the dial indicator installed, release the clamping pressure on the liner, and watch for "spring back" (the liner rising up out of the block). Spring back indicates a twisted o-ring; remove the liner and correct the problem.

  ☐ c. Measure the liner protrusion/height. Record your measurements in Table 3 on the worksheet.

  ☐ d. Adjust height as specified by manufacturer. Shims are common. After making adjustment, remeasure liner protrusion.

☐ 7. When all liners on your engine conform to the tolerances specified by your engine service manual, have your instructor inspect your work, and initial this job sheet.

Instructor's initials ______________

☐ 8. Turn in job ticket when finished.

☐ 9. Clean work area and return tools and materials to proper storage.

Evaluator's Comments: ____

____

____

Unit 3-B, Worksheet for Job Sheet 6

Name ______________________________ Date __________ Attempt number_______

Table 1—Liner Out-of-Round

Cylinder	Diameter "A"	Diameter "B"	Liner Out-of-Round
1 Top			
Bottom			
2 Top			
Bottom			
3 Top			
Bottom			
4 Top			
Bottom			
5 Top			
Bottom			
6 Top			
Bottom			
7 Top			
Bottom			
8 Top			
Bottom			

Table 2—Liner Taper

Cylinder	Diameter "A"	Diameter "B"	Liner Taper
1			
2			
3			
4			
5			
6			
7			
8			

Worksheet for Job Sheet 6

Table 3—Liner Protrusion/Height

Cylinder	Liner Protrusion
#1	
#2	
#3	
#4	
#5	
#6	
#7	
#8	

Manufacturer's specifications:

Maximum liner projection ______________________

Adjacent liner projection ______________________

Maximum variation from greatest to least ______________________

663

PARTS LIST

QTY.	PARTS/MATERIALS	PRICE
TOTAL PARTS/MATERIALS		

SPECIFICATIONS CHECKED

School/Work Name ____________________
Address ____________________
Phone # ____________________

Date In ____________
Date Out ____________

JOB TICKET

Customer Name ____________________
Customer Address ____________________
Customer Phone # ____________________

Vehicle/Equip.	Make & Model	License #/Motor #/Serial #	Speedometer

Condition reported by customer/service requested: ____________________

Services/repairs made: ____________________

LABOR

Customer Authorization

I, the undersigned, have reviewed the required service and parts estimates and authorize this maintenance to be performed with the understanding that I will be notified prior to the performance of any work that significantly exceeds those estimates in time or cost.

____________________ Date ____________

Technician ____________
Supervisor ____________

Job Sheet 6

Unit Contents

Student Components

Student Page

Objective Sheet 4B–3

Information Sheet 4B–5

Job Sheets

1—Remove, Clean, and Inspect a Crankshaft 4B–15
2—Install Main Bearings and Crankshaft 4B–23
3—Perform an In-Frame Bearing Roll-In 4B–27
4—Inspect Viscous Vibration Damper/Harmonic Balancer 4B–33
5—Inspect Bonded Vibration Damper/Harmonic Balancer 4B–39
6—Inspect Flywheel 4B–43

Objective Sheet

Unit Objective

After completing this unit, the student should be able to inspect and service diesel engine crankshafts, bearings, vibration dampers, and flywheels. The student should demonstrate these competencies by completing the job sheets and by scoring a minimum of 85 percent on the written test.

Specific Objectives

After completing this unit, the student should be able to:

1. Match terms related to crankshafts and bearings with their definitions.
2. Identify the parts of a crankshaft.
3. Identify engine design according to crankshaft throws.
4. Select true statements concerning crankshaft throw characteristics.
5. Describe crankshaft balancing methods.
6. Complete statements concerning crankshaft lubrication.
7. Match characteristics of a good bearing with their descriptions.
8. Distinguish among bearing materials and their characteristics.
9. Identify the parts of main and connecting rod bearings.
10. Distinguish between special design features of main bearings.
11. Identify the types of thrust bearings.
12. Describe symptoms of bearing failure.
13. Distinguish between the types of vibration dampers.
14. Select from a list the functions of a flywheel.
15. Remove, clean, and inspect a crankshaft. (Job Sheet 1)
16. Install main bearings and crankshaft. (Job Sheet 2)
17. Perform an in-frame bearing roll-in. (Job Sheet 3)
18. Inspect viscous vibration damper/harmonic balancer. (Job Sheet 4)
19. Inspect bonded vibration damper/harmonic balancer. (Job Sheet 5)
20. Inspect flywheel. (Job Sheet 6)

Information Sheet

Objective 1

Terms and definitions

a. **Bearing**—Half-round sleeve used to support heavy loads

b. **Bearing cap**—Removable half of the housing that holds the bearing shells in place

c. **Bushing**—Full-round sleeve used to support light loads

d. **Companion cylinders**—Pistons that move up and down at the same time, though not necessarily on the same stroke

e. **Connecting rod**—Structural member that transfers the force from the piston to the crankpin

f. **Connecting rod bearing**—Bearing at the big end of the connecting rod in which the crankpin rotates

g. **Crankshaft**—Main shaft of an engine; contains the main bearing journals and crankpins

h. **Crankshaft web**—Non-machined area between the rod journal and the main journal

i. **Crush**—Circumferential interference fit necessary to hold two bearing halves securely in the housing bore

j. **Dynamically balanced**—In balance at operating speeds

k. **End play**—Possible forward and backward (axial) movement of the crankshaft in the main bearing bore or connecting rods on the crankpin

l. **Fillet**—Curved joint between the journal and web that adds strength

m. **Journal**—Part of a shaft that revolves in a bearing

n. **Main bearing**—Bearing that is used to support the crankshaft in the cylinder block

o. **Overload**—Bearing load in excess of the load the bearing was designed to carry

p. **Spread**—Excess of diameter at the outside parting edges in the free state over the housing bore into which the bearing is to be installed

q. **Statically balanced**—In balance at rest

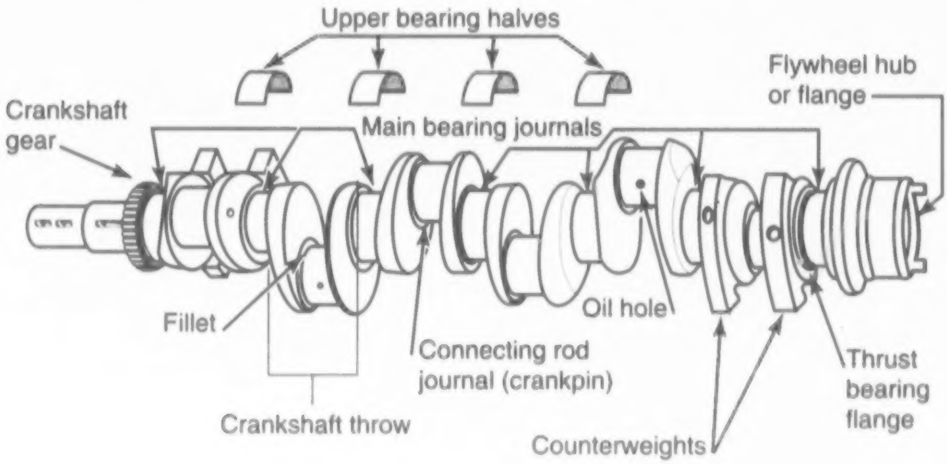
r. **Thrust bearings**—Bearing that limits axial movement (end play) of the crankshaft and prevents wear upon the block itself

s. **Wear**—Gradual decrease in bearing thickness

Objective 2

Parts of a crankshaft

Figure 1

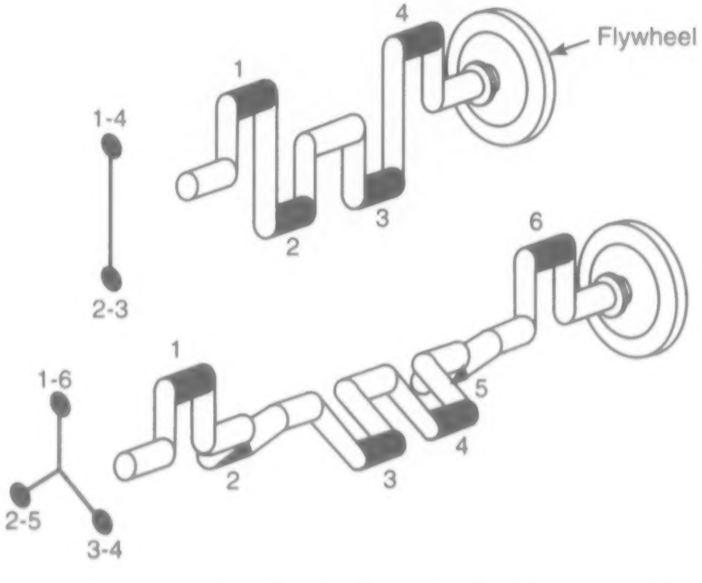

Upper bearing halves
Flywheel hub or flange
Crankshaft gear
Main bearing journals
Fillet
Oil hole
Connecting rod journal (crankpin)
Thrust bearing flange
Crankshaft throw
Counterweights

Objective 3

Crankshaft throw arrangements

a. In-line

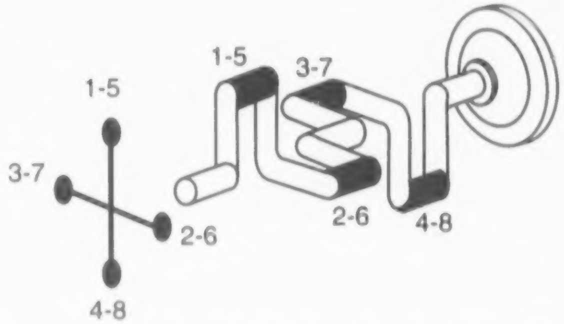
Figure 2


4
Flywheel
1
1-4
3
2
2-3
6
1
1-6
5
4
2
3
2-5
3-4

Reproduced by permission of John Deere Publishing, Deere & Company, Moline, IL. *Engines* © 1991. All rights reserved.

b. V-type

Figure 3



Reproduced by permission of John Deere Publishing, Deere & Company, Moline, IL. *Engines* © 1991. All rights reserved.

Objective 4

Crankshaft throw characteristics

a. Engine operation—Crankshaft throw arrangement:

- Affects engine balance
- Determines vibration levels during engine operation
- Determines firing order

b. Engine design

- In-line engines having even numbers of cylinders have matched throws—two pistons moving in the same direction at the same time. Engines having odd numbers of cylinders do not have matched throws.
- V-type engines typically have two pistons sharing one crankpin. These two pistons are not matched throws, since one piston lags behind the other. However, V-type engines do have matched throws (pistons moving the same direction at the same time), but they are located on different crankpins.

Objective 5

Crankshaft balancing methods

a. Internal method

- Counterweights—Added weight to balance out the weight of the piston and rod
- Balance holes—Precision drilled to remove weight and to dynamically balance the crankshaft

b. External method

- Vibration damper—Absorbs torsional vibrations produced by the firing pulses of each piston; also known as a harmonic balancer
- Flywheel—Weights cast or welded to one side help offset the internal weight of the pistons and rods.

c. Mechanical method—Internal balance shafts

- Gear driven by crankshaft to rotate at twice crankshaft speed.
- Timed so that weight moves in opposite direction of piston—as piston moves up, weight moves down; as piston moves down, weight moves up.
- Opposing motion cancels out the vibration created by the reciprocating weight of the piston and rod.

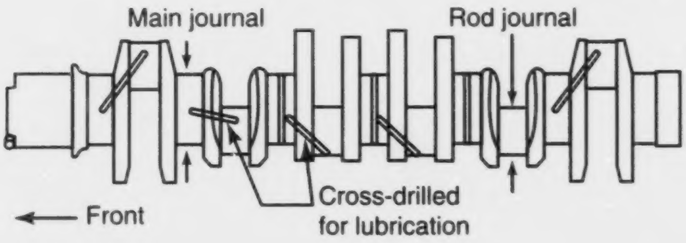
Objective 6

Crankshaft lubrication

a. Crankshaft main journals are fed pressurized oil directly from the main oil gallery.

b. Each connecting rod journal is cross-drilled to receive pressurized oil from an adjacent main journal.

Figure 4



Courtesy of Detroit Diesel Corporation

Objective 7

Characteristics of a good bearing

a. **Conformability**—Ability to adapt to the shape of the crankshaft journal

b. **Corrosion resistance**—Ability to remain unaffected by the acids that form in the lubricating oil as a result of moisture and combustion

c. **Embedability**—Ability to absorb small particles of dirt, metal, or carbon into the bearing material without causing serious bearing damage

d. **Seizure resistance (load-carrying capacity)**—Ability to maintain smooth motion during high-pressure loading from combustion forces

e. **Temperature strength**—Ability to maintain smooth operation at high engine temperatures

f. **Wear rate**—Ability to adequately support the crankshaft, yet not cause wear to the crankshaft journals

Objective 8

Bearing materials and their characteristics

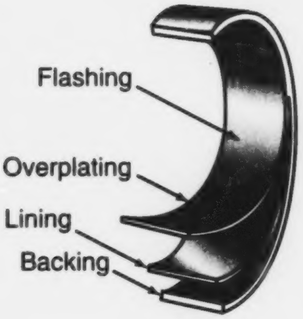
a. **Flashing**—Made of tin plating; allows quick seating of the crankshaft journals and protects bearing prior to installation

b. **Overplating**—Made of alloys of copper, lead, and tin; provides a soft surface to trap dirt, metal, or carbon particles

c. **Lining**—Made of alloys of aluminum, copper, lead, and tin; provides the load-bearing wear surface

d. **Backing**—Made of steel; provides strength for bearing lining

Figure 5

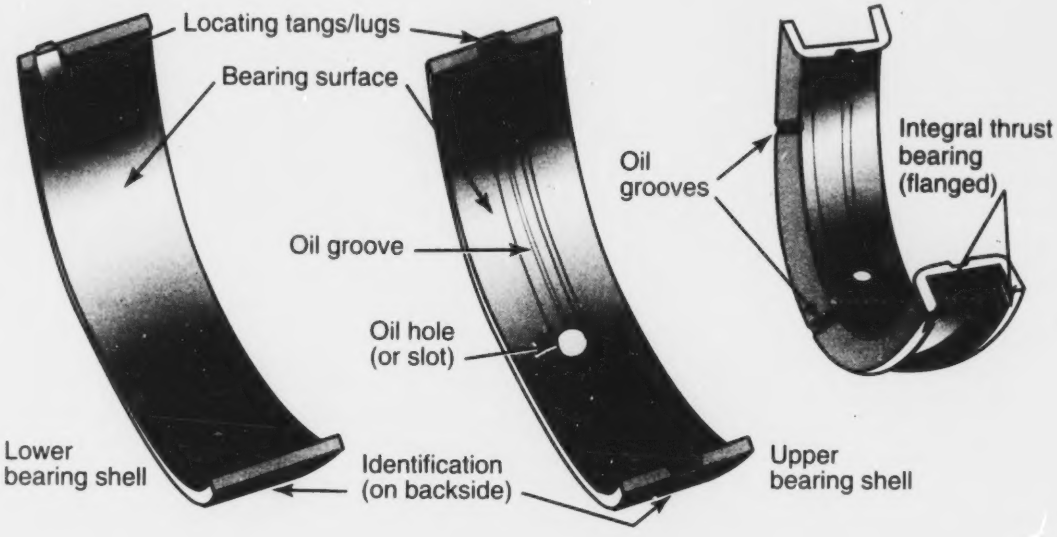


Objective 9

Parts of main and connecting rod bearings

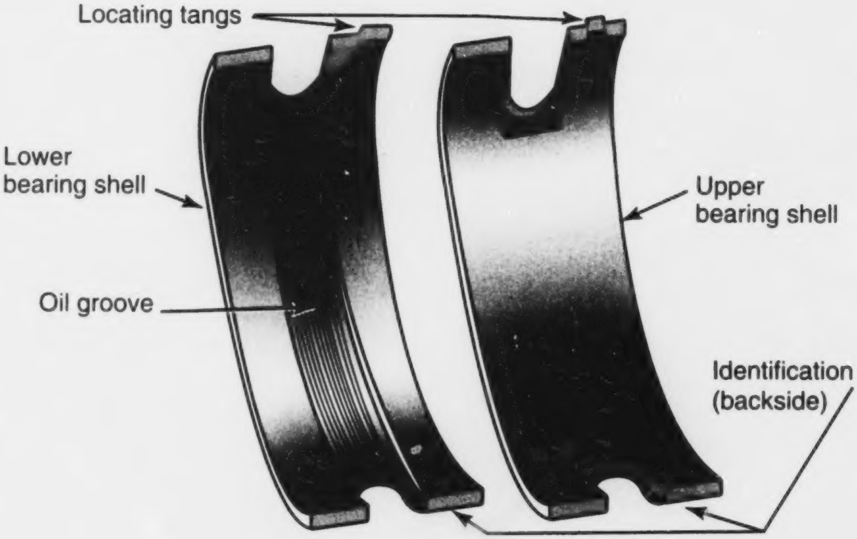
a. Main bearing

Figure 6


Locating tangs/lugs
Bearing surface
Oil grooves
Integral thrust bearing (flanged)
Oil groove
Oil hole (or slot)
Lower bearing shell
Identification (on backside)
Upper bearing shell

b. Connecting rod bearings

Figure 7


Locating tangs
Lower bearing shell
Upper bearing shell
Oil groove
Identification (backside)

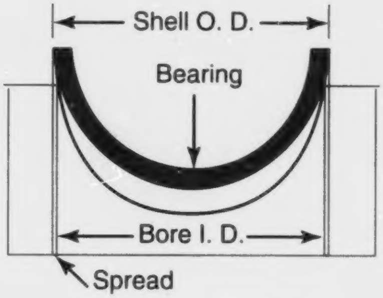
Objective 10

Special design features of main bearings

a. **Spread**

- The outside diameter (O.D.) of the bearing shell is slightly larger than the inside diameter (I.D.) of the housing bore.
- This gives a snap-fit, ensuring that the steel backing conforms to the bore and the bearing stays in the bore during installation.

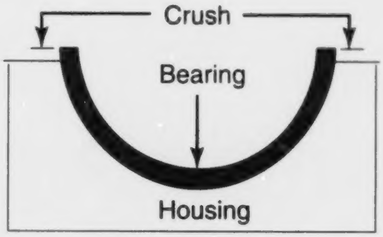
Figure 8



b. **Crush**

- The parting face of the bearing shell protrudes slightly above the parting face of the bearing saddle.
- The bearing shell is pressed into the bearing housing, preventing any shell movement.

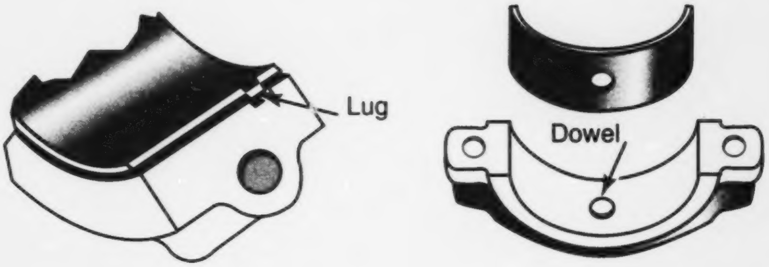
Figure 9



c. **Bearing locating devices**

- Used to keep bearings from rotating or shifting in their housings
- Include locating lugs, tangs, and dowels.

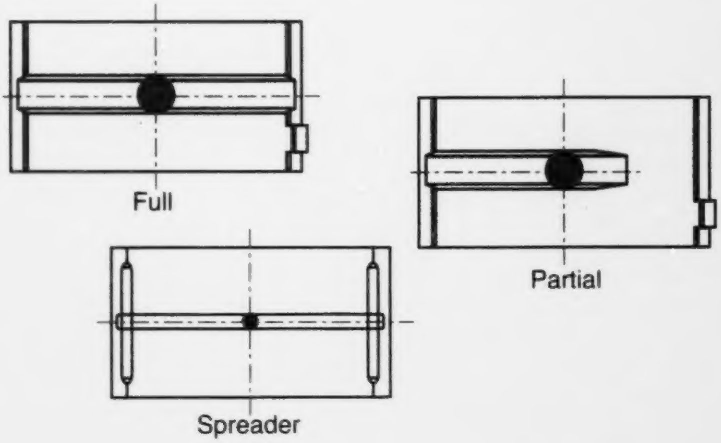
Figure 10



d. **Oil holes and grooves**

- Used to provide lubricating oil to bearing surfaces
- The oil hole is normally in line with the groove and must be aligned with the oil passage hole.

Figure 11—Typical types of bearing oil grooves

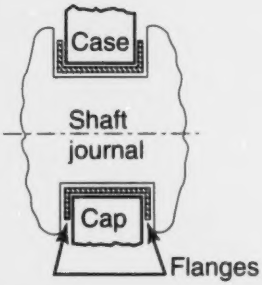


Objective 11

Types of thrust bearings

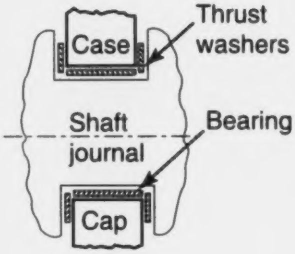
a. Flanged

Figure 12


Case
Shaft
journal
Cap
Flanges

b. Separate

Figure 13


Thrust
washers
Case
Shaft
journal
Bearing
Cap

Reproduced by permission of John Deere Publishing, Deere & Company, Moline, IL. *Engines* © 1991. All rights reserved.

Objective 12

Symptoms of bearing failure

a. Decreasing oil pressure as engine reaches operating temperature

b. Metallic particles in oil

c. Excessive oil consumption

d. Sharp, rhythmic, metallic knocking noise

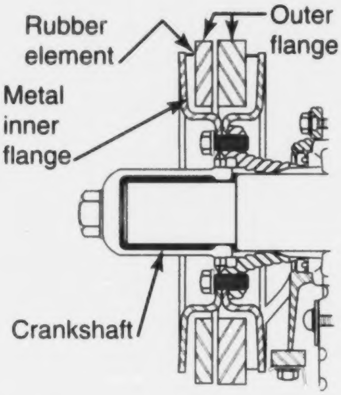
- Rod bearing knock—Usually loudest when load is removed
- Main bearing knock—Heavier sound, usually loudest under load

Objective 13

Types of vibration dampers

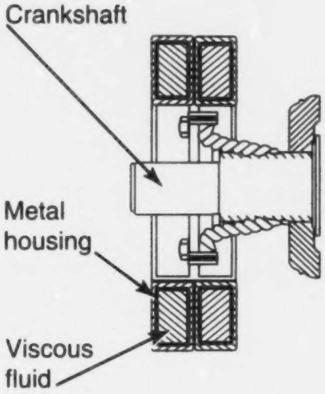
a. Bonded (rubber element)

Figure 14


Rubber element
Outer flange
Metal inner flange
Crankshaft

b. Viscous fluid

Figure 15


Crankshaft
Metal housing
Viscous fluid

Courtesy of Deutz-Allis Corporation

Objective 14

Functions of a flywheel

a. Stores momentum

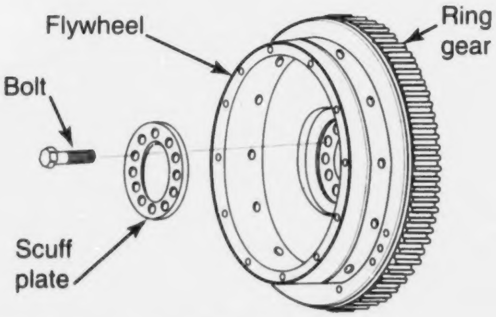
b. Smoothes out piston power pulses

c. Can provide external balance for an engine

d. Provides a mounting surface for the starter ring gear

e. Provides friction surface for clutch disc

Figure 16


Flywheel
Ring gear
Bolt
Scuff plate

Courtesy of Detroit Diesel Corporation

Objective 15

Job Sheet 1—Remove, Clean, and Inspect a Crankshaft

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Engine service manual used correctly	______
• Tools and precision measuring equipment used correctly	______
• Shop safety procedures followed	______
• Work area clean and well organized	______
• Job ticket completed correctly	______

Basic Skills

Reading Writing Mathematics Science Critical Thinking Employability

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, Equipment, and Materials

- Technician's common hand tools
- Appropriate service manual
- Job ticket or work order—one is included or use appropriate one provided at your facility
- Safety equipment
- Engine hoist
- Outside micrometer
- Stiff bristle bore brush
- Precision measuring tools as specified by the instructor
- Crankshaft to be worked on
- Others—as recommended by instructor and equipment service manual

Note: The crankshaft is the largest rotating mass in the block assembly. It must absorb firing pulses of all the cylinders, torsional stresses, and harmonic vibration. To handle this and not self-destruct, the crankshaft must be in excellent mechanical condition. The inspections you will perform in this job sheet will ensure this.

> **Warning**: The crankshaft is heavy and awkward to handle. Severe crushing injuries can result from improper lifting and handling procedures! Get assistance as needed.

Job Sheet 1

Procedure

☐ 1. Locate and follow the appropriate procedure in the service manual.

☐ 2. Complete the accompanying job ticket with all pertinent information.

☐ 3. Make sure the following preliminary tasks have been done.

  ☐ a. Clean engine exterior.

  ☐ b. Drain cooling system.

  ☐ c. Drain crankcase.

  ☐ d. Remove engine and mount on an engine stand.

  ☐ e. Remove accessories and attaching parts.

  ☐ f. Remove flywheel and flywheel housing.

  ☐ g. Remove oil pan and oil pump.

☐ 4. Remove the crankshaft.

  ☐ a. Your engine service manual will contain a complete step-by-step procedure for removing the crankshaft in your specific engine.

  ☐ b. Because of the weight of the crankshaft and the possibility of personal injury and component damage, use a lifting sling or a specialized crankshaft lifting device to remove the crankshaft from the block.

  ☐ c. On the bench, support the crankshaft on V-blocks.

☐ 5. Clean the crankshaft.

  ☐ a. Use solvent to remove all oil, varnish, and carbon from the crankshaft surfaces.

  ☐ b. Use the stiff bristle bore brush to thoroughly clean out all oil passages.

  ☐ c. Use a tap to chase the threads in the flywheel mounting flange.

  ☐ d. After a final rinse, dry the crankshaft with compressed air.

Caution: When using compressed air, be sure to wear eye protection. .

☐ 6. Inspect the crankshaft. Note your findings on the worksheet included.

  ☐ a. Visually inspect.

  - Check all keyways for evidence of cracks or wear.
  - Check the journal surfaces for bluing. This indicates overheating and makes the crankshaft unusable.
  - Check the journals for scoring or ridges.
  - Check oil seal contact surfaces for scoring.
  - Check thrust surfaces for scoring.
  - Check the crankshaft gear for chipped or worn teeth.

  ☐ b. Detect stress cracks.

  - Several inspection methods exist for detecting cracks. Your instructor will determine which specific method you will use. Follow the test equipment directions.
  - Be observant for any of the following:
    - — Circumferential fillet cracks
    - — Cracks beginning at either the fillet or the crankshaft journal hole and running 45° to the crankshaft axis.
  - On the accompanying worksheet, list the type of detection equipment used and the location of any cracks discovered.

☐ 7. Measure journals for out-of-round and taper.

  ☐ a. Out-of-round

  - Measure the journal radius and record your reading in column "A" of the worksheet.
  - Rotate the micrometer 90°, and repeat step #1. Record this measurement in column "B."
  - Subtract the smaller number from the larger, and write the difference in the "journal out-of-round" column.
  - Compare your out-of-round measurements with the wear limits published in the engine service manual.

- ☐ b. Taper
  - Measure the journal radius at one end of the machined area. Record your reading in column "A."
  - Measure the journal radius at the other end of the machined area. Record this reading in column "B."
  - Subtract the smaller number from the larger and record the difference in the "journal taper" column.
  - Compare your measurements with the wear limits published in the engine service manual.

☐ 8. Have your instructor check your work.

☐ 9. Turn in job ticket when finished.

☐ 10. Clean work area and return tools and materials to proper storage.

Evaluator's Comments: ______________________________

____

____

Unit 4-B, Worksheet for Job Sheet 1

Name ______________________________ Date __________ Attempt number ________

1. Keyway condition ______________________________

____

2. Journal overheating ______________________________

____

3. Journal condition ______________________________

____

4. Seal contact surface condition:

Front oil seal ______________________________

Rear oil seal ______________________________

5. Thrust surfaces ______________________________

____

6. Crankshaft gear ______________________________

7. Type of crack detection equipment used:

________Magnetic particle method

________Fluorescent magnetic particle method

________Fluorescent penetrant method

8. Crack description and location

Description	Location
________________	________________
________________	________________
________________	________________
________________	________________

Worksheet for Job Sheet 1

9. Journal out-of-round

Table 1

Journal	A	B	Journal out-of-round
1			
2			
3			
4			
5			
6			
7			

Maximum allowable out-of-round ____________________

10. Journal taper

Table 2

Journal	A	B	Journal taper
1			
2			
3			
4			
5			
6			
7			

Maximum allowable taper ____________________

Instructor's signature ____________________

Job Sheet 1

PARTS LIST

QTY.	PARTS/MATERIALS	PRICE	
TOTAL PARTS/MATERIALS			

SPECIFICATIONS CHECKED

School/Work Name ______________________

Address ______________________

Phone # ______________________

Date In __________

Date Out __________

JOB TICKET

Customer Name ______________________

Customer Address ______________________

Customer Phone # ______________________

Vehicle/Equip.	Make & Model	License #/Motor #/Serial #	Speedometer

Condition reported by customer/service requested: ______________________

Services/repairs made: ______________________

LABOR	

Customer Authorization

I, the undersigned, have reviewed the required service and parts estimates and authorize this maintenance to be performed with the understanding that I will be notified prior to the performance of any work that significantly exceeds those estimates in time or cost.

______________________ Date __________

Technician __________

Supervisor __________

Objective 16

Job Sheet 2—Install Main Bearings and Crankshaft

Name ____________________ Attempt Number ________

Date ____________________ Overall Rating ________

Evaluation Criteria	Rating
• Engine service manual used correctly	______
• Tools and precision measuring equipment used correctly	______
• Shop safety procedures followed	______
• Work area clean and well organized	______
• Job ticket completed correctly	______

Basic Skills

Reading Writing Mathematics Science Critical Thinking Employability

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, Equipment, and Materials

- Technician's common hand tools
- Appropriate service manual
- Job ticket or work order—one is included or use appropriate one provided at your facility
- Safety equipment
- Engine hoist
- Crankshaft lifting tool or sling
- Torque wrench
- Plastigage
- Dial test indicator with magnetic stand
- Crankshaft to be worked on
- Others—as recommended by instructor and equipment service manual

Procedure

☐ 1. Locate and follow the appropriate procedure in the service manual.

☐ 2. Complete the accompanying job ticket with all pertinent information.

☐ 3. Install main bearings and thrust washers.

  ☐ a. Install the main bearing shells per the instructions in the engine service manual.

  ☐ b. Install the thrust washers. If the thrust washer and main bearing are a one piece assembly, then they were already installed in step a.

  ☐ c. Lightly oil the upper bearing shells and thrust washers.

☐ 4. Install crankshaft.

  ☐ a. Using the sling or crankshaft lifting tool, carefully lay the crankshaft in place.

  ☐ b. Once the crankshaft is in place, do not allow it to turn! This might cause some of the bearing shells to shift out of place.

☐ 5. Measure bearing clearance.

  ☐ a. Cut pieces of the Plastigage the width of the bearing shell. Lay one piece on each of the crankshaft main journals.

  ☐ b. Install the main caps and lower bearing shells, and torque the cap bolts as specified in the engine service manual. Do not rotate the crankshaft!

  Note: Do not oil the lower bearing shells. Oil will cause the Plastigage to dissolve.

  ☐ c. Loosen the cap bolts and remove the caps and lower bearing shells. The Plastigage will be stuck to either the bearing shell or the crankshaft journal.

  ☐ d. Use the scale printed on the Plastigage container to measure the bearing oil clearance. The clearances must be within the tolerances published in the engine service manual. List the journal clearances here:

Journal	Journal Clearance	Journal	Journal Clearance
1		5	
2		6	
3		7	
4			

Maximum allowable journal clearance ____________________

☐ e. Use the solvent to clean the Plastigage from the bearing shell or journal. Lightly oil the bearing shell and reinstall the bearing cap.

☐ 6. Use the service manual procedure to seat the thrust bearings and measure the crankshaft end play. Record the clearance below:

Measured end play ____________________

Maximum allowable end play ____________________

☐ 7. Have your instructor check your work.

☐ 8. Turn in job ticket when finished.

☐ 9. Clean work area and return tools and materials to proper storage

Evaluator's Comments: ____

____

____

PARTS LIST

QTY.	PARTS/MATERIALS	PRICE	
TOTAL PARTS/MATERIALS			

SPECIFICATIONS CHECKED

School/Work Name ____________________

Address ____________________

Phone # ____________________

Date In __________

Date Out __________

JOB TICKET

Customer Name ____________________

Customer Address ____________________

Customer Phone # ____________________

Vehicle/Equip.	Make & Model	License #/Motor #/Serial #	Speedometer

Condition reported by customer/service requested: ____________________

Services/repairs made: ____________________

	LABOR	

Customer Authorization

I, the undersigned, have reviewed the required service and parts estimates and authorize this maintenance to be performed with the understanding that I will be notified prior to the performance of any work that significantly exceeds those estimates in time or cost.

____________________ Date __________

Technician __________

Supervisor __________

Objective 17

Job Sheet 3—Perform an In-Frame Bearing Roll-In

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Engine service manual used correctly	______
• Tools and precision measuring equipment used correctly	______
• Shop safety procedures followed	______
• Work area clean and well organized	______
• Job ticket completed correctly	______

Basic Skills

Reading Writing Mathematics Science Critical Thinking Employability

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, Equipment, and Materials

- Technician's common hand tools
- Appropriate service manual
- Job ticket or work order—one is included or use appropriate one provided at your facility
- Safety equipment
- Engine barring tool and breaker bar
- Torque wrench
- Bearing installation tool (roll pin)
- Petroleum jelly
- Plastigage
- New crankshaft main bearing inserts
- Crankshaft to be worked on
- Others—as recommended by instructor and equipment service manual

Guidelines

- Work on only one main bearing at a time. Remove and reinstall the upper and lower bearing shells for each main journal before moving on to the next. This prevents mixing parts.

- Do not use the starter motor to turn the crankshaft. Use the barring tool. This allows greater control, and prevents damaging the new bearings.

- Main bearing caps must **always** be reinstalled in their original position.

Procedure

☐ 1. Locate and follow the appropriate procedure in the service manual.

☐ 2. Complete the accompanying job ticket with all pertinent information.

☐ 3. Drain and remove the oil pan.

☐ 4. If necessary, remove the oil pump and oil pump pickup. If shims are installed between the oil pump and the block, attach them to the pump body with a piece of wire. This will prevent them from being lost.

☐ 5. Starting at the front of the engine, remove the main bearing cap.

☐ 6. Remove the bearing insert from the cap and wipe the cap with a clean lint-free shop towel. Set the cap aside.

☐ 7. Bar the engine over so that the oil delivery hole in the crankshaft is pointing straight down.

☐ 8. Dip the roll pin in the petroleum jelly and insert it in the oil delivery hole.

☐ 9. Bar the crankshaft over 180°. The roll pin will push the bearing insert out ahead of it.

Important: Rotate the crankshaft so that the bearing shell is pushed out from the tang side. Turning the crankshaft the other way damages the bearing shell and leaves behind metal particles.

☐ 10. Remove the old upper bearing shell from the crankshaft journal. (Oil will be holding it in place.)

☐ 11. Lightly oil a new upper bearing shell and place it on the crankshaft journal. Install the roll pin, as in step #7.

☐ 12. Rotate the crankshaft so that the smooth end of the bearing (side away from the tang) enters the block on the tang side of the bearing bore. Be careful not to bar the engine over too far and damage the bearing tang.

☐ 13. Turn the crankshaft back slightly and remove the roll pin.

☐ 14. Install a new lower bearing shell in the clean main bearing cap. Do not oil it at this time.

☐ 15. Place a strip of Plastigage the width of the bearing on the bearing shell and install the bearing cap. Torque the cap bolts evenly to the recommended torque.

Note: Do **not** rotate the crankshaft. This will ruin the Plastigage.

☐ 16. Loosen the cap bolts and remove the bearing cap.

☐ 17. Measure the strip of Plastigage by comparing it to the scale on the side of the envelope it came in. Record your readings on Table 1 of the worksheet.

☐ 18. Wipe the Plastigage off the bearing shell using clean solvent on a clean shop towel.

☐ 19. Dry the bearing shell, lightly oil it with clean engine oil, and reinstall the bearing cap. Torque the bolts evenly to the recommended torque.

☐ 20. Go to the next bearing cap and repeat steps 5-19.

☐ 21. Have your instructor check your work.

☐ 22. Turn in job ticket when finished.

☐ 23. Clean work area and return tools and materials to proper storage.

Evaluator's Comments: ______________________________

____

____

Unit 4-B, Worksheet for Job Sheet 3

Name ______________________ Date __________ Attempt number ________

Engine Identification

a. Manufacturer ______________________

b. Engine model ______________________

c. Main cap bolt torque ______________________

d. Main bearing clearance ______________________

Table 1—Main Bearing Clearance

#1	
#2	
#3	
#4	
#5	
#6	
#7	

PARTS LIST

QTY.	PARTS/MATERIALS	PRICE	
TOTAL PARTS/MATERIALS			

SPECIFICATIONS CHECKED

School/Work Name ______________________

Address ______________________

Phone # ______________________

Date In ____________

Date Out ____________

JOB TICKET

Customer Name ______________________

Customer Address ______________________

Customer Phone # ______________________

Vehicle/Equip.	Make & Model	License #/Motor #/Serial #	Speedometer

Condition reported by customer/service requested: ______________________

Services/repairs made: ______________________

	LABOR	

Customer Authorization

I, the undersigned, have reviewed the required service and parts estimates and authorize this maintenance to be performed with the understanding that I will be notified prior to the performance of any work that significantly exceeds those estimates in time or cost.

______________________ Date ____________

Technician ____________

Supervisor ____________

Objective 18

Job Sheet 4—Inspect Viscous Vibration Damper/Harmonic Balancer

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Engine service manual used correctly	______
• Tools and precision measuring equipment used correctly	______
• Shop safety procedures followed	______
• Work area clean and well organized	______
• Job ticket completed correctly	______

Basic Skills

Reading Writing Mathematics Science Critical Thinking Employability

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, Equipment, and Materials

- Technician's common hand tools
- Appropriate service manual
- Job ticket or work order—one is included or use appropriate one provided at your facility
- Safety equipment
- Outside micrometer
- Dial test indicator with magnetic stand
- Dye penetrant
- Breaker bar and sockets
- Replacement viscous damper, if needed
- Crankshaft to be worked on
- Others—as recommended by instructor and equipment service manual

Procedure

☐ 1. Locate and follow the appropriate procedure in the service manual.

☐ 2. Complete the accompanying job ticket with all pertinent information.

☐ 3. Remove and clean the vibration damper.

  ☐ a. Consult the engine service manual for the procedure to remove the damper.

  ☐ b. Use engine degreaser and steam to thoroughly clean the damper.

☐ c. Dry the damper with compressed air.

> **Warning:** To avoid injuries when using compressed air, always wear eye protection!

☐ 4. Inspect the damper for cracks, leaks, and dents.

☐ a. Visually inspect the damper for nicks, bulges, and surface deterioration.

☐ b. Check for cracks using the dye penetrant. Follow the manufacturer's instructions for application and developing.

☐ c. Note your findings here:

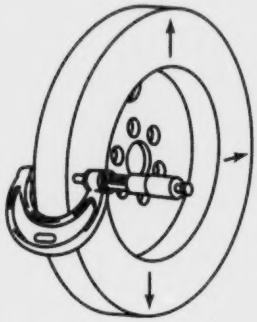
____

____

☐ 5. Inspect damper thickness.

☐ a. Use the outside micrometer to check damper thickness in four places. These measurements should be taken approximately .125″ from the outer edge.

Figure 1



Courtesy of Cummins Engine Company, Inc.

☐ b. Record the four measurements here:

1. _______ 2. _______

3. _______ 4. _______

Maximum allowable difference stated by manufacturer: ___

☐ c. If the measurements exceed the allowable amount, the damper will need to be replaced.

Note: Dampers should also be replaced at overhaul and after a crankshaft or cam noise failure.

> **Warning:** In the following steps, the engine will need to be turned over. To avoid personal injury and equipment damage, do not use the starter motor to do this. Use the accessory driveshaft to turn the engine over.

☐ 6. Install the damper and check for radial runout (eccentricity)

☐ a. Consult the engine service manual for the procedure to install the damper.

☐ b. Use the dial test indicator and magnetic base to measure the runout along the circumference of the damper.

☐ c. Rotate the engine 360°, and record the maximum measured runout here:

____

☐ d. Maximum allowable runout stated by manufacturer:

____

☐ e. If damper radial runout exceeds the allowable amount, stop here and alert your instructor. The damper will need to be replaced.

☐ 7. Check for damper face alignment (wobble).

☐ a. Push the crankshaft to the rear of the engine to fully seat the crankshaft against the thrust washer.

☐ b. Use the dial test indicator and magnetic base to measure runout along the face of the damper.

☐ c. Rotate the engine 360°, and record the maximum measured runout here:

____

☐ d. Maximum allowable runout stated by manufacturer:

____

☐ e. If damper radial runout exceeds the allowable amount, stop here and alert your instructor. The damper will need to be replaced.

☐ 8. Have your instructor check your work.

☐ 9. Turn in job ticket when finished.

☐ 10. Clean work area and return tools and materials to proper storage

Evaluator's Comments: ______________________________________

____

____

700

PARTS LIST

QTY.	PARTS/MATERIALS	PRICE	
TOTAL PARTS/MATERIALS			

SPECIFICATIONS CHECKED

School/Work Name ______________________

Address ______________________

Phone # ______________________

Date In ____________

Date Out ____________

JOB TICKET

Customer Name ______________________

Customer Address ______________________

Customer Phone # ______________________

Vehicle/Equip.	Make & Model	License #/Motor #/Serial #	Speedometer

Condition reported by customer/service requested: ______________________

____

Services/repairs made: ______________________

LABOR	

Customer Authorization

I, the undersigned, have reviewed the required service and parts estimates and authorize this maintenance to be performed with the understanding that I will be notified prior to the performance of any work that significantly exceeds those estimates in time or cost.

______________________ Date ____________

Technician ____________

Supervisor ____________

Objective 19

Job Sheet 5—Inspect Bonded Vibration Damper/Harmonic Balancer

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	**Rating**
• Engine service manual used correctly	______
• Tools and precision measuring equipment used correctly	______
• Shop safety procedures followed	______
• Work area clean and well organized	______
• Job ticket completed correctly	______

Basic Skills

Reading Writing Mathematics Science Critical Thinking Employability

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, Equipment, and Materials

- Technician's common hand tools
- Appropriate service manual
- Job ticket or work order—one is included or use appropriate one provided at your facility
- Safety equipment
- Outside micrometer
- Dial test indicator with magnetic stand
- Dye penetrant
- Breaker bar and sockets
- Replacement bonded damper, if needed
- Crankshaft to be worked on
- Others—as recommended by instructor and equipment service manual

Procedure

☐ 1. Locate and follow the appropriate procedure in the service manual.

☐ 2. Complete the accompanying job ticket with all pertinent information.

☐ 3. Remove and clean the vibration damper.

  ☐ a. Consult the engine service manual for the procedure to remove the damper.

  ☐ b. Use engine degreaser and steam to thoroughly clean the damper.

- ☐ c. Dry the damper with compressed air.

> **Warning:** To avoid injuries when using compressed air, always wear eye protection!

☐ 4. Inspect the damper for cracks or deterioration.

- ☐ a. Visually inspect the bonding material between the inner hub and the outer inertia ring for signs of cracking or disintegration.
- ☐ b. Check the outer inertia ring for signs of slippage or misalignment.
- ☐ c. Check the hub and inertia ring for cracks using the dye penetrant. Follow the manufacturer's instructions for application and developing.
- ☐ d. Note your findings here:

  ____

  ____

- ☐ e. If you find misalignment, cracks in the metal components, or signs of rubber separation, stop here and notify your instructor.

☐ 5. Install the damper and check for radial runout (eccentricity).

- ☐ a. Consult the engine service manual for the procedure to install the damper.
- ☐ b. Use the dial test indicator and magnetic base to measure the runout along the circumference of the damper.
- ☐ c. Rotate the engine 360°, and record the maximum measured runout here:

  ____

- ☐ d. Maximum allowable runout stated by manufacturer:

  ____

- ☐ e. If damper radial runout exceeds the allowable amount, the damper will need to be replaced.

☐ 6. Have your instructor check your work.

☐ 7. Turn in job ticket when finished.

☐ 8. Clean work area and return tools and materials to proper storage

Evaluator's Comments: ______________________________

____

____

PARTS LIST

QTY.	PARTS/MATERIALS	PRICE	
TOTAL PARTS/MATERIALS			

SPECIFICATIONS CHECKED

School/Work Name ______________________

Address ______________________

Phone # ______________________

Date In ______________

Date Out ______________

JOB TICKET

Customer Name ______________________

Customer Address ______________________

Customer Phone # ______________________

Vehicle/Equip.	Make & Model	License #/Motor #/Serial #	Speedometer

Condition reported by customer/service requested: ______________________

Services/repairs made: ______________________

LABOR	

Customer Authorization

I, the undersigned, have reviewed the required service and parts estimates and authorize this maintenance to be performed with the understanding that I will be notified prior to the performance of any work that significantly exceeds those estimates in time or cost.

______________________ Date ______________

Technician ______________

Supervisor ______________

Objective 20

Job Sheet 6—Inspect Flywheel

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Engine service manual used correctly	______
• Tools and precision measuring equipment used correctly	______
• Shop safety procedures followed	______
• Work area clean and well organized	______
• Job ticket completed correctly	______

Basic Skills

Reading Writing Mathematics Science Critical Thinking Employability

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, Equipment, and Materials

- Technician's common hand tools
- Appropriate service manual
- Job ticket or work order—one is included or use appropriate one provided at your facility
- Safety equipment
- Breaker bar and sockets
- Torque wrench
- Crankshaft and flywheel to be worked on
- Others—as recommended by instructor and equipment service manual

Procedure

☐ 1. Locate and follow the appropriate procedure in the service manual.

☐ 2. Complete the accompanying job ticket with all pertinent information.

☐ 3. Remove and clean the flywheel.

  ☐ a. Consult the engine service manual for the procedure to remove the flywheel.

  ☐ b. Use engine degreaser and steam to clean the flywheel.

  ☐ c. Use compressed air to dry the flywheel.

> **Warning:** To avoid injuries when using compressed air, always wear eye protection!

☐ 4. Visually inspect the components for signs of wear, cracking, or overheating.

- ☐ a. Starter ring gear teeth
    - Excess wear
    - Broken/missing teeth
- ☐ b. Clutch contact surface
    - Bluing/heat checking
    - Scoring
    - Warpage
- ☐ c. Crankshaft flange contact surface
    - Hairline cracks
    - Fretting
- ☐ d. Pilot bearing bore
- ☐ e. Crankshaft wear sleeve
- ☐ f. Note your findings here:

____

____

____

☐ 5. Install flywheel and measure runout.

- ☐ a. Consult the engine service manual for the procedure to install the flywheel.
- ☐ b. Use the dial test indicator and magnetic base to check the following runout.
    - Flywheel housing bore runout
    - Flywheel housing face runout
    - Flywheel face runout
    - Pilot bearing bore runout

☐ c. Record your readings and compare to manufacturer's specifications.

	Your readings	Mfg. specs
• Flywheel housing bore runout	__________	________
• Flywheel housing face runout	__________	________
• Flywheel face runout	__________	________
• Pilot bearing bore runout	__________	________

☐ d. If the measured runout exceeds the maximum allowable runout, stop here and alert your instructor. The flywheel will need to be remachined or replaced.

☐ 6. Have your instructor check your work.

☐ 7. Turn in job ticket when finished.

☐ 8. Clean work area and return tools and materials to proper storage.

Evaluator's Comments: ____

____

____

PARTS LIST

QTY.	PARTS/MATERIALS	PRICE	
TOTAL PARTS/MATERIALS			

SPECIFICATIONS CHECKED

School/Work Name ____________________

Address ____________________

Phone # ____________________

Date In ____________

Date Out ____________

JOB TICKET

Customer Name ____________________

Customer Address ____________________

Customer Phone # ____________________

Vehicle/Equip.	Make & Model	License #/Motor #/Serial #	Speedometer

Condition reported by customer/service requested: ____________________

Services/repairs made: ____________________

	LABOR	

Customer Authorization

I, the undersigned, have reviewed the required service and parts estimates and authorize this maintenance to be performed with the understanding that I will be notified prior to the performance of any work that significantly exceeds those estimates in time or cost.

____________________ Date ____________

Technician ____________

Supervisor ____________

712

711

Pistons and Connecting Rods

Unit Contents

Student Components

Student Page

Objective Sheet 5B-3

Information Sheet 5B-5

Job Sheets

1—Remove, Disassemble, and Inspect a Piston and Connecting Rod Assembly 5B-15
2—Measure Piston-to-Cylinder Wall Clearance and Ring End Gap 5B-23
3—Assemble and Install Piston and Connecting Rod Assembly . . . 5B-27

713

Objective Sheet

Unit Objective

After completing this unit, the student should be able to remove, inspect, service, and install pistons and connecting rods. The student should demonstrate these competencies by completing the job sheets and by scoring a minimum of 85 percent on the written test.

Specific Objectives

After completing this unit, the student should be able to:

1. Match terms related to pistons and connecting rods with their definitions.
2. Label the primary components of a piston and connecting rod assembly.
3. Match piston and connecting rod components with their functions.
4. Identify parts of a piston.
5. Match piston parts with their functions.
6. Distinguish between common piston designs.
7. Identify types of piston crown designs.
8. Distinguish among the types of piston rings.
9. Identify common types of piston ring end gaps.
10. Identify piston ring designs.
11. Match piston ring designs with their characteristics.
12. Identify the parts of a connecting rod.
13. Match connecting rod parts with their descriptions.
14. Describe common causes of abnormal piston wear.
15. List possible causes of high oil consumption and blow-by.
16. Remove, disassemble, and inspect a piston and connecting rod assembly. (Job Sheet 1)
17. Measure piston-to-cylinder wall clearance and ring end gap. (Job Sheet 2)
18. Assemble and install piston and connecting rod assembly. (Job Sheet 3)

714

Information Sheet

Objective 1

Terms and definitions

a. **Blow-by**—Combustion gases that leak past the piston rings into the crankcase; causes oil contamination and leaks

b. **Cam-ground**—Machining the piston slightly oval in shape to allow for uneven expansion; at operating temperatures, the piston becomes perfectly round

c. **Match marks**—Identifying marks on the connecting rod and cap that allow them to be reassembled exactly as manufactured

d. **Piston ring end gap**—Amount of clearance between the split ends of the piston rings

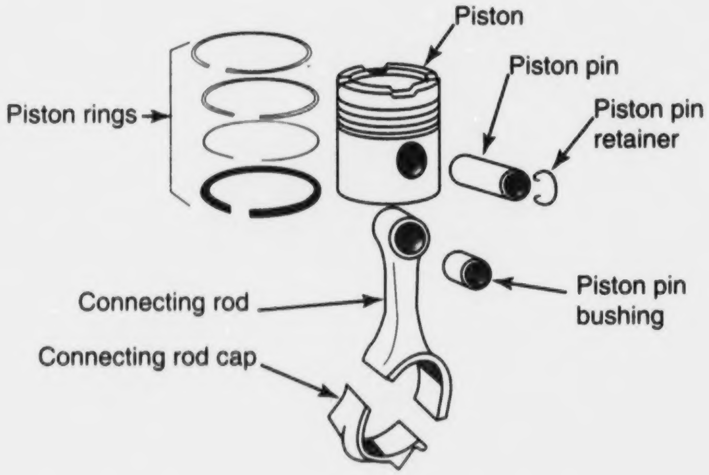
e. **Piston ring lands**—Piston area that forms a wall between the ring grooves

f. **Piston pin boss**—Reinforced area on both sides of the piston that supports the piston pin

Objective 2

Primary components of a piston and connecting rod assembly

Figure 1


Piston
Piston pin
Piston pin retainer
Piston rings
Connecting rod
Piston pin bushing
Connecting rod cap

Information Sheet

Objective 3

Functions of piston and connecting rod components

a. **Piston crown**—Moves back and forth in cylinder to transmit engine force and motion; converts heat into reciprocating motion

Note: Piston crown design affects compression ratios.

b. **Piston (wrist) pin**—Provides pivot point for the connecting rod; may be floating, bolted, or tapered to fit bore

c. **Piston pin bushing**—Provides a replaceable wear surface for the piston pin

d. **Piston pin retainer**—Locks the piston pin in place, preventing it from contacting and damaging the cylinder wall; can be either spring steel clips or Teflon® end plug

e. **Piston rings**—Seal the cylinder above the piston; contain the combustion gases and prevent blow-by

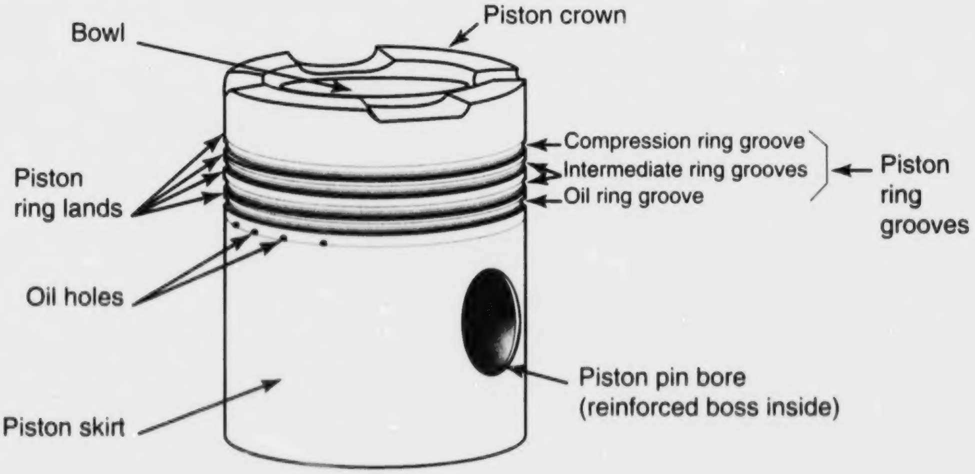
f. **Connecting rod**—Joins piston to crankshaft and transmits force and motion

g. **Connecting rod cap**—Holds the lower half of the bearing shell

Objective 4

Parts of a piston

Figure 2


Bowl
Piston crown
Compression ring groove
Intermediate ring grooves
Oil ring groove
Piston ring grooves
Piston ring lands
Oil holes
Piston pin bore (reinforced boss inside)
Piston skirt

Objective 5

Functions of piston parts

a. **Piston crown**—Receives the force of combustion

b. **Bowl**—Concave area in the crown that forms part of the combustion chamber

c. **Piston ring lands**—Support the piston rings

d. **Oil holes**—Allow oil to escape after the oil control rings wipe it off the cylinder wall

e. **Piston skirt**—Guides the piston inside the cylinder, prevents cocking, and minimizes side wear

f. **Piston pin bore**—Receives connecting rod end and piston pin to form assembly

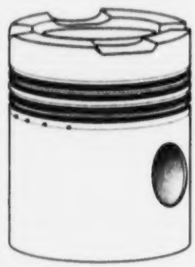
g. **Piston ring grooves**—Machined areas that hold the piston rings

Objective 6

Common piston designs

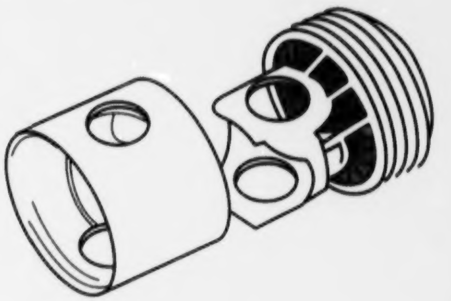
a. Single piece (trunk-type)

Figure 3



b. Multi-piece (articulated or cross-head type)

Figure 4

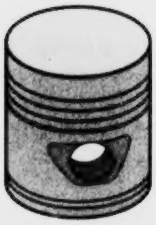


Objective 7

Types of piston crown designs

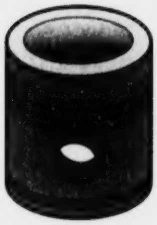
a. Flat head—Precombustion/indirect injection

Figure 5



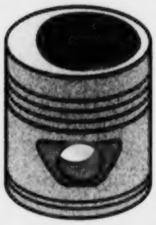
b. Concave head—Direct injection

Figure 6



c. Irregular head—Angled/side-loaded injectors

Figure 7



Objective 8

Types of piston rings and their functions

a. **Top compression ring(s) (Top ring)**

- Seals the cylinder above the piston, preventing hot gases from leaking into the crankcase
- During the power stroke, hot gases flow behind the ring, forcing it against the cylinder wall.
- Most diesel engines use at least two compression rings; some use as many as four.
- Top of the ring is usually identified with a dot or by the word "TOP."
- Some top and intermediate compression rings have one edge beveled. The instructions in the ring set will state whether the beveled edge goes up or down.

b. **Intermediate compression ring(s)**

- Provide a strong secondary gas seal to help contain combustion gases.

- Downward motion of the piston twists the ring in its groove, forcing the sharp ring edge against the cylinder wall.
- On the intake stroke, this prevents excess oil from being sucked into the upper cylinder; on the power stroke, this aids the compression rings in sealing the cylinder.
- Top of the ring is usually identified with a dot or by the word "TOP."

  Note: "TOP" doesn't mean it's the top ring; it just means it's the top side of this ring.

c. **Oil control ring(s)**

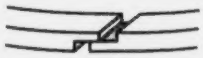
- Prevent excess oil from flooding the combustion chamber
- Usually is a multi-piece ring, consisting of two scraper rails and an expander/spacer.
- On the downstroke, the scraper rails remove excess oil from the cylinder walls, returning it to the crankcase. A thin film is left behind for piston/ring lubrication.

Objective 9

Common types of piston ring end gaps

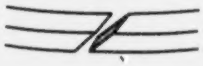
Step

Figure 8



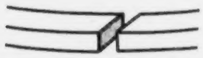
Angle

Figure 9



Butt

Figure 10

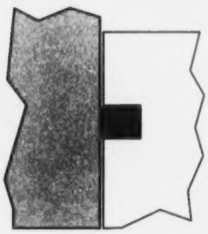


Objective 10

Piston ring designs

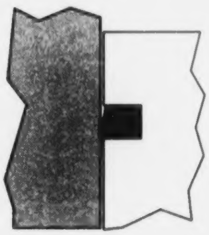
a. Rectangular ring

Figure 11



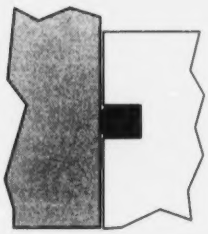
b. Taper-faced ring

Figure 12



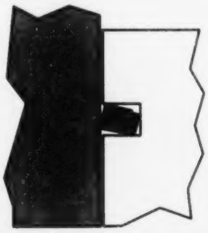
c. Barrel-faced ring

Figure 13



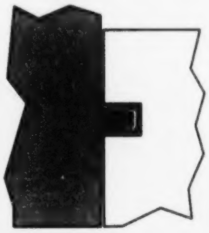
d. Inside bevel ring

Figure 14



e. Keystone ring

Figure 15



Objective 11

Characteristics of piston ring designs

a. **Rectangular ring**—Common ring design that distributes sealing pressure along the entire face of the ring; typically used on a top compression ring

b. **Taper-faced ring**—Concentrates sealing pressure along one narrow strip of the ring face; breaks in and seats quickly and has better oil control than the rectangular ring, but only moderate blow-by control

c. **Barrel-faced ring**—Quick-seating ring with excellent blow-by control; commonly used as a top compression ring

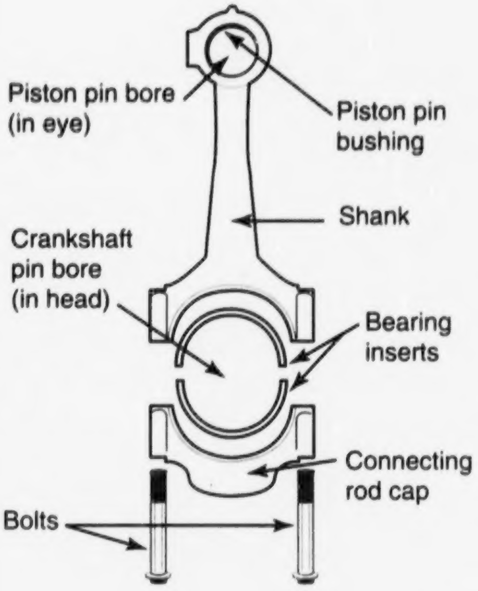
d. **Inside bevel ring**—Designed to cock inside the ring groove during the downstroke in order to concentrate all sealing pressure against a small, sharp edge, which provides an excellent seal; generally used as an intermediate ring

e. **Keystone ring**—Uses tapered sides to improve sealing and minimize sticking; available in many different face styles (barrel, taper) for specific applications, especially turbocharging

Objective 12

Parts of a connecting rod

Figure 16


Piston pin bore (in eye)
Piston pin bushing
Shank
Crankshaft pin bore (in head)
Bearing inserts
Connecting rod cap
Bolts

Objective 13

Connecting rod parts and their descriptions

a. **Piston pin bore (eye)**—Little end of the rod that is machined to hold the piston pin bushing

b. **Shank**—Body of the rod, usually having I-beam cross-section

c. **Bearing inserts**—Replaceable load-bearing wear surfaces for the crankshaft rod journals

d. **Connecting rod cap**

- Connecting rod and cap are forged as one piece, then precision machined and cut
- Rod caps are matched to each rod and should not be intermixed
- Match marks allow the cap to be reinstalled correctly. If the match marks are reversed, the connecting rod bearing will be destroyed
- Rod caps may be straight (standard) or angled

e. **Crankshaft pin bore (head)**—Big end of the rod that is machined to hold the crankshaft bearing insert

f. **Bolts**—Used to hold the connecting rod and cap together

Objective 14

Common causes of abnormal piston wear

a. Scoring

- Grit in engine oil or fuel
- Dust from unfiltered intake air
- Carbon particles from the combustion chamber
- Insufficient warm-up
- Inadequate lubrication
- Inadequate cooling
- Lugging/overloading

b. Corrosion

- Water leaking into the cylinder
- Low engine operating temperature
- Incorrect engine oil
- Acids from condensation/combustion forming in the lubricating oil

c. Ignition erosion

- Timing set incorrectly (advanced/retarded)
- Detonation damage to piston crown

d. Mechanical damage

- Piston pin retainers installed incorrectly
- Rings/lands damaged during piston installation
- Connecting rod bent
- Excessive crankshaft end play
- Cylinder bore centerline not true

Objective 15

Possible causes of high oil consumption and blow-by

a. Worn rings

b. Excess piston-to-cylinder wall clearance

c. Rings installed incorrectly

d. Broken rings

e. Stuck rings

f. Slots in the oil control ring clogged

g. Mechanical damage to piston or cylinder wall

h. Worn connecting rod bearings

i. Missing/leaking piston pin retainers

Objective 16

Job Sheet 1—Remove, Disassemble, and Inspect a Piston and Connecting Rod Assembly

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Engine service manual used correctly	______
• Tools and precision measuring equipment used correctly	______
• Shop safety procedures followed	______
• Work area clean and well organized	______
• Job ticket completed correctly	______

Basic Skills

Reading Writing Mathematics Science Critical Thinking Employability

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, Equipment, and Materials

- Technician's common hand tools
- Appropriate service manual
- Job ticket or work order—one is included or use appropriate one provided at your facility
- Safety equipment
- Cylinder liner puller/installer (if required)
- Piston ring expander
- Piston ring compressor
- Feeler gauge set
- Inside calipers/micrometer
- Engine to be worked on
- Others—as recommended by instructor and equipment service manual

Procedure

☐ 1. Locate and follow the appropriate procedure in the service manual.

☐ 2. Complete the accompanying job ticket with all pertinent information.

☐ 3. Remove the piston and connecting rod (or cylinder pack).

  ☐ a. Consult your engine service manual to determine whether the piston and rod are removed by themselves, or if the liner/piston/rod are removed at the same time as a complete unit (cylinder pack).

☐ b. Follow the directions given for component removal, keeping in mind the following points:

- Before removing rod caps, ensure that one side of the rod cap and rod are match-marked. Typically, the cylinder number is used for this.
- Keep the rings and bearing shells with the piston and rod from which they were removed.

☐ 4. Disassemble the connecting rod and piston.

☐ a Your engine service manual will walk you through the step-by-step procedure for disassembling the piston and rod.

☐ b. Use the ring expanding tool to remove the piston rings, and only expand each ring just enough to remove it without scratching the piston. Overextending the rings causes them to break.

☐ c. When disassembling cross-head type pistons, use a paint pencil to mark the piston dome and skirt so that they can be reassembled correctly.

☐ 5. Clean the components.

☐ a. Ring grooves can be cleaned with a ring groove cleaner. Pay careful attention to the following:

- Support the piston in a padded fixture to prevent it from moving.
- Before using the tool, be sure that the proper bit sizes are installed.
- Hold the tool square to the piston, and as it is rotated, take care that only carbon and ash are removed (not metal).

☐ b. Because most trunk-type pistons are tin-plated, abrasive cleaning or wire brushing cannot be used to remove carbon. There are several approved cleaning solutions that will not harm the aluminum alloy or the tin plate. Consult your instructor on which method you should use.

☐ c. Cross-head type pistons have a removable piston dome that is not tin-plated. Glass beading is suggested. Do **not** glass bead the piston skirt. Again, consult your instructor on which cleaning procedure you should use. Fill in the information on the worksheet.

- ☐ d. During the cleaning process, ensure that the following are cleaned thoroughly:
  - Inside surfaces of the piston dome and skirt
  - Oil return slots/holes in the oil control ring grooves
  - Oil passages

☐ 6. Inspect piston and connecting rod for wear.

- ☐ a. Closely check the piston for the following:
  - Scoring
  - Cracking
  - Damaged ring grooves or pin bosses
  - Blue discoloration indicating overheating

  Note your findings in Table A on the worksheet. If you see any of the above, consult your instructor. Any of these conditions will require piston replacement.

- ☐ b. Follow your manual's instructions for ring groove inspection. Place a checkmark in the appropriate column in Table A if the ring grooves pass inspection.

- ☐ c. Inspect the piston pin, paying careful attention to the following:
  - Fretting
  - Cracking
  - Heat discoloration
  - Pin outside diameter

  Note your findings in Table A.

☐ 7. Inspect the connecting rod for wear.

- ☐ a. Closely inspect the connecting rod and cap for the following:
  - Heat discoloration around the little end or big end
  - Straightness (no twisting or bending of the rod beam)

- Pin bushing condition and inside diameter
- Big end condition and inside diameter
- Dents or gouges in the rod surface
- Rod/cap mating surface for fretting corrosion

☐ b. Note your findings in the appropriate column in Table B.

☐ c. Although the pin bushing may look good, it is a good idea to replace it during an overhaul as a matter of course. The added cost is minimal, and it ensures the rod is ready to function satisfactorily for the life of the overhaul. Your engine service manual will contain the instructions for this procedure.

☐ 8. Have your instructor check your work.

☐ 9. Turn in job ticket when finished.

☐ 10. Clean work area and return tools and materials to proper storage.

Evaluator's Comments: ______________________________

____

____

Unit 5-B, Worksheet for Job Sheet 1

Name ______________________ Date __________ Attempt number ________

Engine manufacturer ______________________________

Engine type/model ______________________________

Piston type ______________________________

Piston cleaning procedure ______________________________

____

Table A

Cylinder #	Piston Condition	Ring Groove Condition	Piston Pin Condition	Piston Pin OD
1				
2				
3				
4				
5				
6				
7				
8				

Worksheet for Job Sheet 1

Table B

Cylinder #	Connecting Rod Condition	Rod Straightness	Pin Bushing Condition	Big End ID	Rod/Cap Mating Surface
1					
2					
3					
4					
5					
6					
7					
8					

PARTS LIST

QTY.	PARTS/MATERIALS	PRICE	
TOTAL PARTS/MATERIALS			

SPECIFICATIONS CHECKED

School/Work Name ______________________

Address ______________________

Phone # ______________________

Date In ____________

Date Out ____________

JOB TICKET

Customer Name ______________________

Customer Address ______________________

Customer Phone # ______________________

Vehicle/Equip.	Make & Model	License #/Motor #/Serial #	Speedometer

Condition reported by customer/service requested: ______________________

____

Services/repairs made: ______________________

LABOR	

Customer Authorization

I, the undersigned, have reviewed the required service and parts estimates and authorize this maintenance to be performed with the understanding that I will be notified prior to the performance of any work that significantly exceeds those estimates in time or cost.

______________________ Date ____________

Technician ____________

Supervisor ____________

Objective 17

Job Sheet 2—Measure Piston-to-Cylinder Wall Clearance and Ring End Gap

Name ____________________ Attempt Number ________

Date ____________________ Overall Rating ________

Evaluation Criteria	Rating
• Engine service manual used correctly	____
• Tools and precision measuring equipment used correctly	____
• Shop safety procedures followed	____
• Work area clean and well organized	____
• Job ticket completed correctly	____

Basic Skills

Reading Writing Mathematics Science Critical Thinking Employability

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, Equipment, and Materials

- Technician's common hand tools
- Appropriate service manual
- Job ticket or work order—one is included or use appropriate one provided at your facility
- Safety equipment
- Feeler gauge set
- Shop towels
- Engine to be worked on
- Others—as recommended by instructor and equipment service manual

Procedure

☐ 1. Locate and follow the appropriate procedure in the service manual.

☐ 2. Complete the accompanying job ticket with all pertinent information.

☐ 3. Measure piston-to-cylinder wall clearance.

  ☐ a. With the rings removed, install the piston upside down into the bore. Push it into the bore until the bottom of the piston skirt is at least 1" below the top of the cylinder/liner.

  ☐ b. Using the feeler gauges, determine which blade gives a smooth, snug fit between the piston and the cylinder wall. Record your findings in Table A of the worksheet.

- ☐ c. Repeat this procedure for each piston, being sure to keep each piston with its cylinder.
- ☐ d. Compare this clearance figure with the engine manufacturer's recommended clearances. If your cylinder clearance exceeds the recommendation, the block will need to be rebored, or the cylinder and liner will need to be replaced with a new cylinder pack.

☐ 4. Measure ring end gap.

- ☐ a. Insert the piston rings into the cylinder bore/cylinder liner one at a time. Place the first ring about 1/2" above the bottom of the cylinder bore/cylinder liner. Place the next ring in the center, and the third ring 1/2" from the top of the bore/liner. Use the piston/piston dome to position each ring and square it within the bore.
- ☐ b. Beginning with the top ring, measure the gap with a feeler gauge. Record your findings in Table A.
- ☐ c. After measuring the top ring, remove it and measure the next ring. Record this information in Table A.
- ☐ d. Repeat this procedure with each ring for each piston.
- ☐ e. Compare your ring end gaps with the engine manufacturer's recommendations.

☐ 5. Turn in job ticket when finished.

☐ 6. Clean work area and return tools and materials to proper storage.

Evaluator's Comments: ______________________________

____

____

Unit 5-B, Worksheet for Job Sheet 2

Name ______________________________ Date ____________ Attempt number________

Table A

Cylinder	Piston-to-Cylinder Wall Clearance	Ring End Gap		
		Top Ring	Middle Ring	Bottom Ring
1				
2				
3				
4				
5				
6				
7				
8				

734

PARTS LIST

QTY.	PARTS/MATERIALS	PRICE	
TOTAL PARTS/MATERIALS			

SPECIFICATIONS CHECKED

School/Work Name ______________________

Address ______________________

Phone # ______________________

Date In ____________

Date Out ____________

JOB TICKET

Customer Name ______________________

Customer Address ______________________

Customer Phone # ______________________

Vehicle/Equip.	Make & Model	License #/Motor #/Serial #	Speedometer

Condition reported by customer/service requested: ______________________

Services/repairs made: ______________________

LABOR	

Customer Authorization

I, the undersigned, have reviewed the required service and parts estimates and authorize this maintenance to be performed with the understanding that I will be notified prior to the performance of any work that significantly exceeds those estimates in time or cost.

______________________ Date ____________

Technician ____________

Supervisor ____________

Objective 18

Job Sheet 3—Assemble and Install Piston and Connecting Rod Assembly

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Engine service manual used correctly	______
• Tools and precision measuring equipment used correctly	______
• Shop safety procedures followed	______
• Work area clean and well organized	______
• Job ticket completed correctly	______

Basic Skills

Reading Writing Critical Thinking Employability

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, Equipment, and Materials

- Technician's common hand tools
- Appropriate service manual
- Job ticket or work order—one is included or use appropriate one provided at your facility
- Safety equipment
- Torque wrench
- Dial test indicator with magnetic stand
- Plastigage
- Ring expander
- Ring compressor
- Cylinder liner installer
- Engine to be worked on (If 2-cycle engine, refer to service manual for procedure)
- Others—as recommended by instructor and equipment service manual

Procedure

☐ 1. Locate and follow the appropriate procedure in the service manual.

☐ 2. Complete the accompanying job ticket with all pertinent information.

☐ 3. Install piston on the connecting rod.

  ☐ a. Refer to the engine service manual for this procedure. Piston design—multi-piece crosshead, or single piece trunk-type—varies from engine to engine, and so does the reassembly process.

- ☐ b. Trunk-type pistons—If the piston pin is a press fit, heat the connecting rod eye area to approximately 450°F before attempting to install the pin. Failure to do this will destroy the pin bushing.
- ☐ c. Cross-head pistons—These connecting rods use a free-floating pin that is bolted to the connecting rod. Use new bolts for reassembly.

☐ 4. Install rings on the piston.

- ☐ a. Holding the connecting rod, dip the piston in clean motor oil. (A large, clean coffee can is great for this.)
- ☐ b. Install the rings from bottom to top, starting with the oil control rings. Pay close attention to the following:
  - If the oil control ring uses a separate spring-type expander, don't allow the ends to overlap. This will ruin the ring and score the piston walls.
  - Oftentimes, top ring, middle ring, and bottom ring have different part numbers. Pay attention to make sure you are installing the correct ring in the correct groove.
  - Make sure that the compression rings are installed right side up. Most of these use a dot or "T" to identify the top of the ring.
  - Stagger the ring gaps according to the engine manufacturer's instructions. Failure to do this will result in lost compression and increased oil consumption.
  - Measure the clearance between each compression ring and its groove. Compare your measurements to the tolerances called for in the engine service manual.

☐ 5. Install piston and rod assembly in the cylinder bore/liner.

- ☐ a. Prior to installing the ring compressor, apply clean engine oil to the cylinder walls, and again to the rings.
- ☐ b. Recheck the position of all ring gaps.
- ☐ c. Install the ring compressor.
- ☐ d. Install rod bolt protectors/guides.

☐ e. Install and lubricate the upper bearing shells as specified by manufacturer.

☐ f. Line up the rod with the crankshaft and insert the piston in the cylinder bore. Using a hammer handle, firmly push the piston through the ring compressor and into the cylinder bore.

Note: If the piston stops moving, DO NOT force it by hitting the piston crown with the hammer handle! STOP and check for a ring caught on the edge of the cylinder bore. Using force causes damage.

☐ g. Guide the rod protectors over the crankshaft journal, and push the piston until the connecting rod seats against the crankshaft rod journal.

☐ 6. Check rod bearing clearances and end play as specified by manufacturer in service manual.

☐ 7. After removing all traces of Plastigage, oil the bearing shell, and install the cap. Torque to specs.

☐ 8. Have your instructor check your work.

☐ 9. Turn in job ticket when finished.

☐ 10. Clean work area and return tools and materials to proper storage.

Evaluator's Comments: ____________________

____

____

Job Sheet 3

PARTS LIST

QTY.	PARTS/MATERIALS	PRICE	
TOTAL PARTS/MATERIALS			

SPECIFICATIONS CHECKED

School/Work Name ____________________

Address ____________________

Phone # ____________________

Date In ____________

Date Out ____________

JOB TICKET

Customer Name ____________________

Customer Address ____________________

Customer Phone # ____________________

Vehicle/Equip.	Make & Model	License #/Motor #/Serial #	Speedometer

Condition reported by customer/service requested: ____________________

Services/repairs made: ____________________

LABOR	

Customer Authorization

I, the undersigned, have reviewed the required service and parts estimates and authorize this maintenance to be performed with the understanding that I will be notified prior to the performance of any work that significantly exceeds those estimates in time or cost.

____________________ Date ____________

Technician ____________

Supervisor ____________

Unit 6-B

Camshafts, Trains, and Timing

Unit Contents

Student Components

Student Page

Objective Sheet 6B–3

Information Sheet 6B–5

Job Sheets

1—Remove, Clean, and Inspect a Camshaft 6B–13
2—Remove, Inspect, and Install Cam Bushings 6B–17
3—Install a Camshaft and Set Cam Timing 6B–21

Unit 6-B Camshafts, Trains, and Timing

Objective Sheet

Unit Objective

After completing this unit, the student should be able to identify, service, and repair camshafts, gear trains, and valve trains in both two-stroke and four-stroke diesel engines. The student should demonstrate these competencies by completing the job sheets and by scoring a minimum of 85 percent on the written test.

Specific Objectives

After completing this unit, the student should be able to:

1. Match terms related to camshafts, trains, and timing with their definitions.
2. Label the primary parts of a camshaft.
3. Distinguish between the types of camshafts.
4. Complete statements concerning the operation of a camshaft.
5. Match the parts of a cam lobe with their definitions.
6. Identify the parts of a valve train.
7. Complete statements concerning valve actuation.
8. Distinguish between two-stroke and four-stroke valve timing.
9. Describe the types of camshaft bushings.
10. Distinguish between types of cam followers and lifters.
11. Match methods of driving the camshaft with their descriptions.
12. Identify the components in a typical gear train.
13. Complete statements concerning gear timing.
14. Remove, clean, and inspect a camshaft. (Job Sheet 1)
15. Remove, inspect, and install cam bushings. (Job Sheet 2)
16. Install a camshaft and set cam timing. (Job Sheet 3)

Information Sheet

Objective 1

Terms and definitions

a. **Backlash**—Clearance between meshed gears

b. **Cam follower**—Device that drives the push rod to operate the valve

c. **Cam lobe**—Oval-shaped, machined part of the camshaft that opens the valve

Note: Cam lobe profile determines engine operating characteristics.

d. **Duration**—Amount of time (in crankshaft degrees) that the valve is open

e. **Overlap**—Amount of time (in crankshaft degrees) that both valves are open

Note: Overlap has a great effect on cylinder scavenging.

f. **Temp-a-Stic®**—Heat-sensitive crayon that melts at 300°F

g. **Train**—Series of moving mechanical parts that transmit and modify motion

Examples: Valve train, gear train

h. **Valve clearance**—Distance between cam lobe and other valve train components, which allows for part expansion at operating temperature

i. **Valve crosshead**—Bridge-like component located between rocker arm and valves that allows one cam lobe to open two valves simultaneously

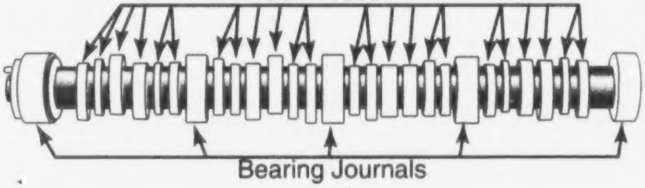
Objective 2

Primary parts of a camshaft

a. Cam lobes

b. Bearing journals

Figure 1



Objective 3

Types of camshafts

a. Diesel engine with injection nozzles has two cam lobes per cylinder.

- One cam lobe to actuate intake valve(s)
- One cam lobe to actuate exhaust valve(s)

b. Diesel engine with mechanical or electronic fuel injectors has three cam lobes per cylinder.

- One lobe to actuate intake valve(s)
- One lobe to actuate exhaust valve(s)
- One lobe to actuate fuel injector

  Note: The size of the cam affects speed.

Objective 4

Operation of a camshaft

a. **Valve train**

- Components that open and close the valves (intake and exhaust)
- Driven by the camshaft

b. **Gear train**

- Series of gears that transfer motion from crankshaft to camshaft
- Driven by crankshaft

Objective 5

Parts of a cam lobe

a. **Valve lift**—Projection on the cam that determines how far the valve will open

Note: Rocker arms use offset fulcrums to increase this by approximately 1.5:1.

b. **Base circle**—Camshaft diameter at the lobe

- **Inner base circle**—Camshaft diameter at the beginning of the opening ramp
- **Outer base circle**—Camshaft diameter at the lobe tip

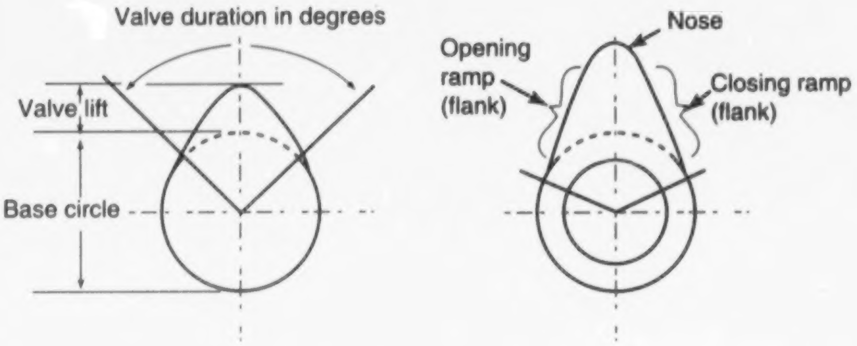
  Note: The difference between inner base circle and outer base circle determines lift.

c. **Ramp flank**—Contour on each side of the nose that determines how quickly the valve opens and closes

Note: The quicker the valve is opened, the sooner the cylinder can begin to fill or empty.

d. **Nose**—Contour that determines how long the valve remains open at maximum lift

Figure 2


Valve duration in degrees
Valve lift
Base circle
Nose
Opening ramp (flank)
Closing ramp (flank)

Objective 6

Parts of a valve train

a. Valve

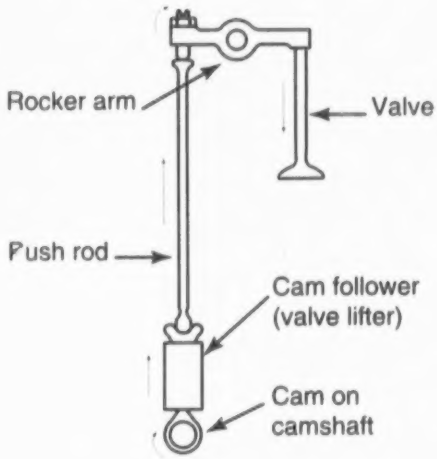
b. Rocker arm

c. Push rod

d. Cam follower (valve lifter)

e. Cam on camshaft

Figure 3


Rocker arm
Valve
Push rod
Cam follower (valve lifter)
Cam on camshaft

Objective 7 **Valve actuation**

a. **Cam in block**

- Camshaft is mounted in the cylinder block.
- Reciprocating motion is transmitted up through the block by push rods.

b. **Cam in head**

- Camshaft is mounted in the cylinder head.
- Motion is transmitted directly from the camshaft to the cam follower or rocker arm. Push rods are not used.

Objective 8 **Valve timing**

a. **Two-stroke cycle diesel engine**

- Camshaft turns at the same speed as crankshaft.
- Exhaust valve is opened and closed once during one revolution of the crankshaft.

b. **Four-stroke cycle diesel engine**

- Camshaft turns at one-half the speed of crankshaft.
- Each intake and exhaust valve is opened and closed once during two revolutions of the crankshaft.

Objective 9 **Types of camshaft bushings**

a. **One-piece**—Press-fit design

b. **Two-piece**—Snap-fit in the bearing saddles

Objective 10 **Types of cam followers and lifters**

a. **Solid lifter**

- Lifter base is ground slightly convex, causing the lifter to rotate in its bore during valve opening; this evenly distributes wear across the cam and lifter contact surface.
- Requires periodic adjustment
- May be mushroom-shaped or cylindrical-shaped, with or without rollers

b. **Hydraulic lifter**

- Uses engine oil pressure to pump up an internal plunger, maintaining zero valve clearance
- Self-adjusting; requires no periodic maintenance
- Typically used in light- or medium-duty applications

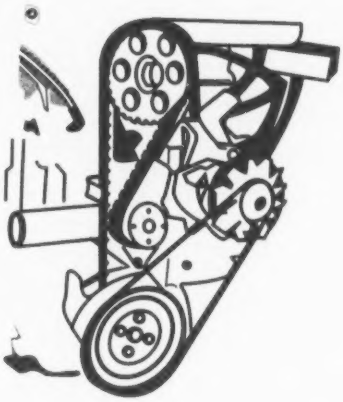
Objective 11

Methods of driving the camshaft

a. **Belt**

- Little noise or vibration; belt acts as a damper
- Spring-loaded or hydraulic tensioners eliminate maintenance or inspections.
- Recommended replacement is every 60,000 to 75,000 miles.

Figure 4

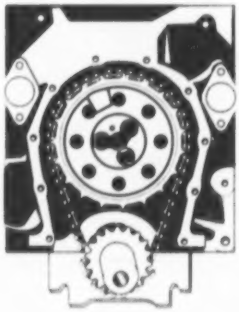


748

b. **Chain**

- More noise generated than a belt-drive system
- Very little power is lost due to friction; most efficient means of power transmission available
- Very long operational life
- Chains tend to stretch; must be adjusted or replaced

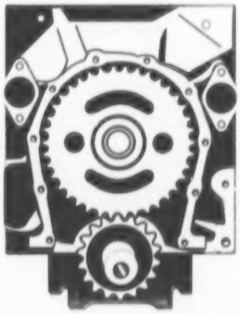
Figure 5



c. **Gear**

- More accurate than either belt or chain; no timing variations due to stretch
- Very long service life, far outlasting belt and chain drives
- Higher friction loss than belt or chain
- Higher noise levels than belt or chain

Figure 6

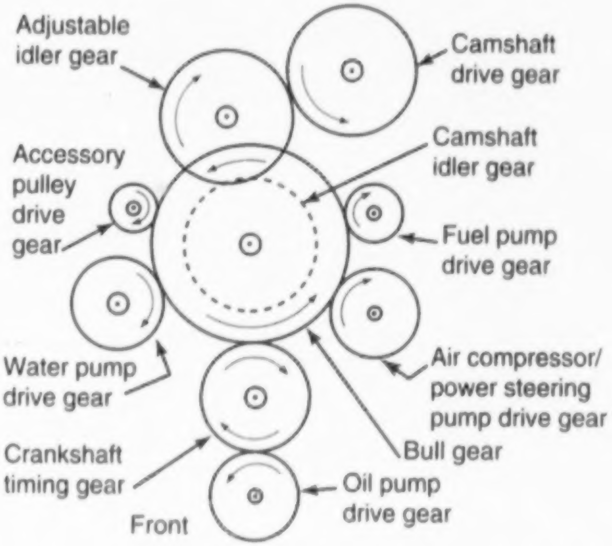


749

Objective 12

Components in a typical gear train

Figure 7


Adjustable idler gear
Camshaft drive gear
Camshaft idler gear
Accessory pulley drive gear
Fuel pump drive gear
Water pump drive gear
Air compressor/ power steering pump drive gear
Bull gear
Crankshaft timing gear
Oil pump drive gear
Front

Courtesy of Detroit Diesel Corporation

Objective 13

Gear timing

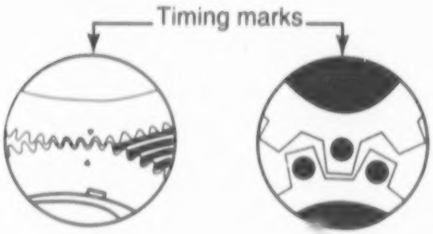
a. Gear teeth are marked with dots, lines, or arrows. The marks are matched up during assembly.

b. Timing mark alignment synchronizes camshaft and crankshaft.

c. Because of the different reduction ratios between the gears, some engines take many revolutions to line up all the timing marks again.

d. Typical gears that are marked to ensure correct valve timing include crankshaft gears, camshaft gears, and idler gears.

Figure 8


Timing marks

Objective 14

Job Sheet 1—Remove, Clean, and Inspect a Camshaft

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Engine service manual used correctly	______
• Tools and precision measuring equipment used correctly	______
• Shop safety procedures followed	______
• Work area clean and well organized	______
• Job ticket completed correctly	______

Basic Skills

Reading Writing Mathematics Science Critical Thinking Employability

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, Equipment, and Materials

- Technician's common hand tools
- Appropriate service manual
- Job ticket or work order—one is included or use appropriate one provided at your facility
- Safety equipment
- Cleaning solvent
- Stiff bristle brush
- Precision measuring equipment
- Engine to be worked on
- Others—as recommended by instructor and equipment service manual

Guidelines

- Handle the camshaft carefully. Do not allow the journals or lobes to bang against the block during removal or installation.

- If lifters are removed, keep them matched to their lifter bore and camshaft lobe. Don't mix them up. Different lifters have different wear patterns. Putting one in the wrong bore will quickly destroy the cam lobe and lifter base.

Procedure

☐ 1. Locate and follow the appropriate procedure in the service manual.

☐ 2. Complete the accompanying job ticket with all pertinent information.

☐ 3. Remove camshaft.

☐ 4. Clean the camshaft.

  ☐ a. Clean all parts using clean solvent and a stiff-bristle brush.

  ☐ b. Thoroughly clean all oil passages.

  ☐ c. Dry parts with compressed air.

☐ 5. Visually inspect the camshaft and cam followers for cracks, scoring, galling, and pitting as specified in the service manual. Record your observations on the worksheet.

☐ 6. Measure the camshaft bearing journals. Compare your measurements to the manufacturer's specifications. Record your measurements on the worksheet and compare them to the manufacturer's specifications.

☐ 7. Measure the camshaft lift at the lobe.

  ☐ a. First, measure the camshaft outer base circle (heel-to-toe). This is the largest measurement you can make on the camshaft lobe.

  ☐ b. Next, measure the inner base circle (side-to-side).

  ☐ c. Finally, subtract inner base circle from outer base circle. The result is the cam lift at the lobe. Record your measurements on the worksheet and compare them to the manufacturer's specifications.

☐ 8. Have your instructor check your work.

☐ 9. Turn in job ticket when finished.

☐ 10. Clean work area and return tools and materials to proper storage.

Evaluator's Comments: ____

____

____

Unit 6-B, Worksheet for Job Sheet 1

Name ______________________________ Date __________ Attempt number ________

1. Visual inspection

   a. Camshaft lobes

      ________OK ________Scored ________Worn ________Pitted

   b. Camshaft journals

      ________OK ________Scored ________Worn ________Pitted

   c. Cam followers

      ________OK ________Scored ________Worn ________Pitted

2. Camshaft journals

   a. Manufacturer's specification for journal diameter ____________________

   b. Measured journal diameters

      1. __________
      2. __________
      3. __________
      4. __________
      5. __________
      6. __________
      7. __________

3. Camshaft lobes

   a. Manufacturer's specification for cam lift ____________________________

   b. Measured lift at the lobe

      1. Intake __________
         Exhaust __________
      2. Intake __________
         Exhaust __________
      3. Intake __________
         Exhaust __________
      4. Intake __________
         Exhaust __________
      5. Intake __________
         Exhaust __________
      6. Intake __________
         Exhaust __________

Job Sheet 1

PARTS LIST

QTY.	PARTS/MATERIALS	PRICE	
TOTAL PARTS/MATERIALS			

SPECIFICATIONS CHECKED

School/Work Name ______________________

Address ______________________

Phone # ______________________

Date In ____________

Date Out ____________

JOB TICKET

Customer Name ______________________

Customer Address ______________________

Customer Phone # ______________________

Vehicle/Equip.	Make & Model	License #/Motor #/Serial #	Speedometer

Condition reported by customer/service requested: ______________________

____

Services/repairs made: ______________________

LABOR	

Customer Authorization

I, the undersigned, have reviewed the required service and parts estimates and authorize this maintenance to be performed with the understanding that I will be notified prior to the performance of any work that significantly exceeds those estimates in time or cost.

______________________ Date ____________

Technician ____________

Supervisor ____________

Objective 15

Job Sheet 2—Remove, Inspect, and Install Cam Bushings

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Engine service manual used correctly	______
• Tools and precision measuring equipment used correctly	______
• Shop safety procedures followed	______
• Work area clean and well organized	______
• Job ticket completed correctly	______

Basic Skills

Reading Writing Mathematics Science Critical Thinking Employability

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, Equipment, and Materials

- Technician's common hand tools
- Appropriate service manual
- Job ticket or work order—one is included or use appropriate one provided at your facility
- Safety equipment
- Measuring instruments—Dial bore gauge, inside micrometer, or snap gauge
- Cam bushing driver
- Black felt tip pen
- Engine to be worked on
- Others—as recommended by instructor and equipment service manual

Guidelines

- When installing cam bushings, seat them securely on the driver. This will prevent misalignment in the bushing bore and damage to the bushing.

- Make sure that the oil hole in the bushing lines up with the oil hole in the bushing bore.

Procedure

☐ 1. Locate and follow the appropriate procedure in the service manual.

☐ 2. Complete the accompanying job ticket with all pertinent information.

☐ 3. With the camshaft bushings installed in the block, use a dial bore gauge, an inside micrometer or a snap gauge to measure the camshaft bushing inner diameter.

1. ______________
2. ______________
3. ______________
4. ______________
5. ______________
6. ______________
7. ______________

Manufacturer's specification for bushing I.D. __________________

☐ 4. Remove camshaft bushings.

- ☐ a. Place the bushing driver into the bushing to be removed.
- ☐ b. Place the guide cone on the bushing bar and insert this assembly into the bushing.
- ☐ c. Make sure that the guide cone is securely seated against another bushing bore so that no misalignment of the driving bar or bushing can occur.
- ☐ d. Holding the bar firmly, strike the driving end solidly with a large hammer. When the bushing is out, remove it from the driver. Place it on the workbench, in order, with the other removed bushings.

☐ 5. Inspect bushing condition.

- ☐ a. Clean all parts in clean solvent and dry with lint-free towels.
- ☐ b. Compare bearings to illustrations in the service manual concerning acceptable/unacceptable conditions.
- ☐ c. List results on the job ticket.
- ☐ d. Consult with your instructor to determine whether or not to reuse the bearings.

- ☐ 6. Install cam bushings.
    - ☐ a. Install the bushings on the driver without the drive bar.
    - ☐ b. Use a black felt tip pen and draw a line across the bushing, marking the oil hole. Now mark the oil hole in the block, just above the bushing bore.
    - ☐ c. Place the bushing and driver in front of the bore. Make sure the black mark on the bushing lines up with the black mark above the bore.
    - ☐ d. Repeat steps for other bushings.
    - ☐ e. Carefully inspect each installed bushing to ensure that no damage has occurred, and that the oil holes line up.
- ☐ 7. Lubricate the cam journals and lobes, and install the cam. You should be able to rotate it by hand, with no binding.
- ☐ 8. Have your instructor check your work.
- ☐ 9. Turn in job ticket when finished.
- ☐ 10. Clean work area and return tools and materials to proper storage.

Evaluator's Comments: ______________________________

____

____

PARTS LIST

QTY.	PARTS/MATERIALS	PRICE	
TOTAL PARTS/MATERIALS			

SPECIFICATIONS CHECKED

School/Work Name ______________________

Address ______________________

Phone # ______________________

Date In __________

Date Out __________

JOB TICKET

Customer Name ______________________

Customer Address ______________________

Customer Phone # ______________________

Vehicle/Equip.	Make & Model	License #/Motor #/Serial #	Speedometer

Condition reported by customer/service requested: ______________________

Services/repairs made: ______________________

LABOR	

Customer Authorization

I, the undersigned, have reviewed the required service and parts estimates and authorize this maintenance to be performed with the understanding that I will be notified prior to the performance of any work that significantly exceeds those estimates in time or cost.

______________________ Date __________

Technician __________

Supervisor __________

Objective 16

Job Sheet 3—Install a Camshaft and Set Cam Timing

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Engine service manual used correctly	______
• Tools and precision measuring equipment used correctly	______
• Shop safety procedures followed	______
• Work area clean and well organized	______
• Job ticket completed correctly	______

Basic Skills

Reading Writing Mathematics Science Critical Thinking Employability

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, Equipment, and Materials

- Technician's common hand tools
- Appropriate service manual
- Job ticket or work order—one is included or use appropriate one provided at your facility
- Safety equipment
- Temp-a-Stic® or soft solder
- Dial indicator
- Feeler gauge
- Engine to be worked on
- Others—as recommended by instructor and equipment service manual

Guidelines

- Before reassembly:
  - Make sure all gears have visible timing marks.
  - Replace any gear that has worn or rough teeth. (The manufacturer may recommend that certain gears be replaced as a set.)
- Do not use heat if the gears can be installed cold.
- Lubricate the end of the puller that contacts the gear shaft.

Job Sheet 3

Procedure

☐ 1. Locate and follow the appropriate procedure in the service manual.

☐ 2. Complete the accompanying job ticket with all pertinent information.

☐ 3. If the camshaft key and gear have been removed, reinstall them on the camshaft according to the manufacturer's instructions.

Note: If the manufacturer allows it, the gears can be heated to ease assembly. Heat the gears to about 300° either by using an acetylene torch or by dipping the gear in hot oil. If using a torch, don't hold it close enough to turn the gear blue. (That's too hot.) Heat the gear slowly and evenly. The temperature can be checked by using either a Temp-a-Stic® or soft solder. Both melt around 300°.

☐ 4. Install the camshaft and gear assembly, paying attention to line up the timing marks.

☐ 5. Check the camshaft timing to see that it conforms to the manufacturer's specifications. Some engine manufacturers provide offset keys to allow the camshaft to be advanced or retarded in 2° increments.

☐ 6. Check the camshaft end play using a dial indicator. Record your measurements below.

Manufacturer's specification for end play ____________________

Measured gear lash ____________________

☐ 7. Check camshaft drive gear lash using either a feeler gauge or a dial indicator. Record your measurements below.

Manufacturer's specification for end play ____________________

Measured end play ____________________

☐ 8. Install cam followers.

☐ 9. Have your instructor check your work.

☐ 10. Turn in job ticket when finished.

☐ 11. Clean work area and return tools and materials to proper storage.

Evaluator's Comments: ____________________

____

____

Job Sheet 3

PARTS LIST

QTY.	PARTS/MATERIALS	PRICE	
TOTAL PARTS/MATERIALS			

SPECIFICATIONS CHECKED

School/Work Name ______________________________

Address ______________________________

Phone # ______________________________

Date In ______________

Date Out ______________

JOB TICKET

Customer Name ______________________________

Customer Address ______________________________

Customer Phone # ______________________________

Vehicle/Equip.	Make & Model	License #/Motor #/Serial #	Speedometer

Condition reported by customer/service requested: ______________________________

____

Services/repairs made: ______________________________

____

____

____

____

____

____

____

____

____

____

____

LABOR	

Customer Authorization

I, the undersigned, have reviewed the required service and parts estimates and authorize this maintenance to be performed with the understanding that I will be notified prior to the performance of any work that significantly exceeds those estimates in time or cost.

______________________________ Date ______________

Technician ______________

Supervisor ______________

Cylinder Head Assemblies

Unit Contents

Student Components

Student Page

Objective Sheet 7B-3

Information Sheet 7B-5

Assignment Sheet

1—Locate and Label Intake and Exhaust Valves 7B-13

Job Sheets

1—Clean and Inspect a Cylinder Head 7B-15
2—Recondition a Cylinder Head 7B-19
3—Install a Cylinder Head Assembly and Adjust Valves 7B-25

765

Objective Sheet

Unit Objective

After completing this unit, the student should be able to distinguish between basic cylinder head designs, identify parts of a valve assembly, and list common cylinder head and valve problems. The student should also be able to inspect, service, and install cylinder head assemblies. The student should demonstrate these competencies by completing the assignment sheet and job sheets and by scoring a minimum of 85 percent on the written test.

Specific Objectives

After completing this unit, the student should be able to:

1. Match terms related to a cylinder head assembly with their definitions.
2. State the functions of the cylinder head.
3. Distinguish between basic cylinder head designs.
4. Label the parts of a typical valve.
5. Match the parts of a valve with their functions.
6. Label basic valve assembly components.
7. Match valve assembly components with their functions.
8. Arrange in order the steps in the operation of a valve rotator.
9. List common cylinder head problems.
10. Select from a list common valve/seat problems.
11. Locate and label intake and exhaust valves. (Assignment Sheet 1)
12. Clean and inspect a cylinder head. (Job Sheet 1)
13. Recondition a cylinder head. (Job Sheet 2)
14. Install a cylinder head assembly and adjust valves. (Job Sheet 3)

Information Sheet

Objective 1

Terms and definitions

a. **Cam follower**—Intermediate contact between camshaft and push rod or rocker arm; converts the camshaft's rotating motion into reciprocating motion

b. **Crosshead (bridge)**—Allows one rocker arm or cam follower to open two valves at the same time

c. **Fuel injection nozzle**—Valve assembly that delivers atomized fuel to the combustion chamber

d. **Interference angle**—Small difference between valve face angle and valve seat angle that provides a narrow leak-free contact area; as the valve gets hot, the valve head expands to fully contact the valve seat

e. **Poppet valve**—Valve design characterized by a flat sealing disk with a perpendicular stem, opened by a camshaft and closed by a spring

f. **Turbulence**—High velocity swirling of air within the combustion chamber

g. **Valve face angle**—Angle between the valve face and the valve stem

i. **Valve seat angle**—Angle between the seat surface and the cylinder head surface

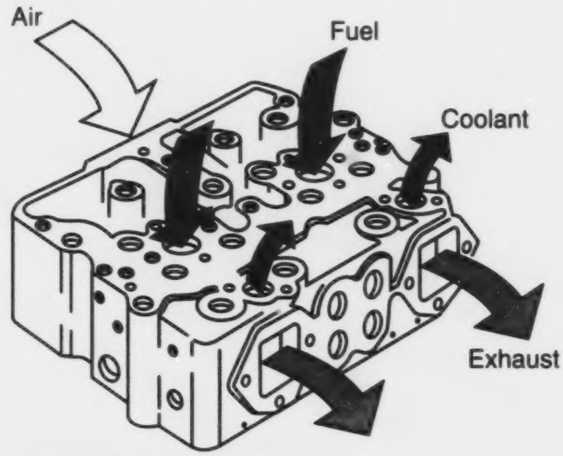
Objective 2

Functions of the cylinder head

a. Contains the passages for air (fresh and exhaust), fuel, and coolant

b. Forms the upper part of the combustion chamber

Figure 1



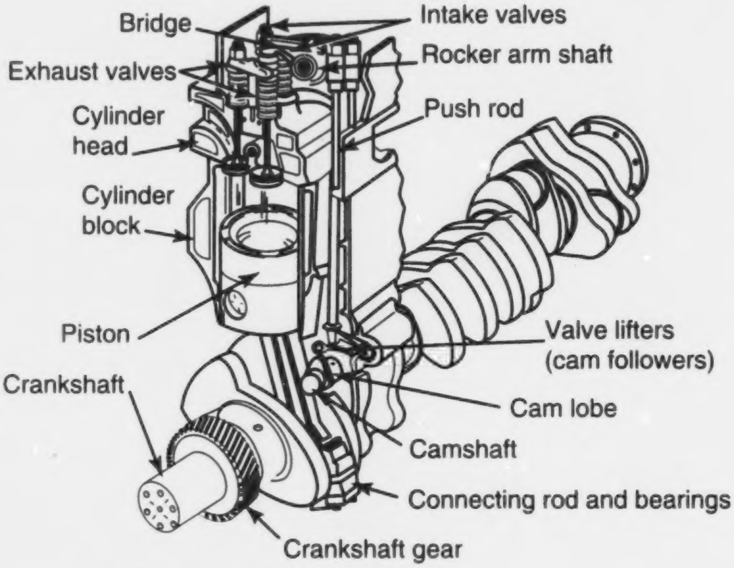
Courtesy of Cummins Engine Company, Inc.

Objective 3

Basic differences between basic cylinder head designs

a. **Cam-in-block**—Engine design that uses push rods and rocker arms to transfer motion from a block-mounted camshaft

Figure 2


Bridge
Intake valves
Rocker arm shaft
Exhaust valves
Cylinder head
Push rod
Cylinder block
Piston
Valve lifters (cam followers)
Crankshaft
Cam lobe
Camshaft
Connecting rod and bearings
Crankshaft gear

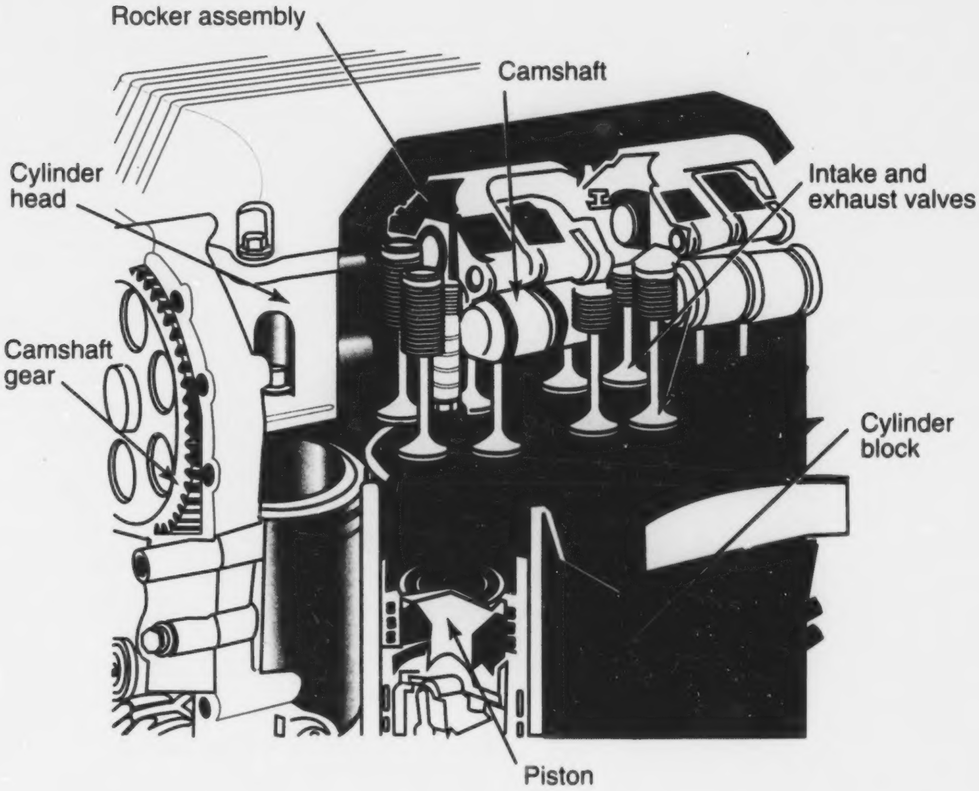
Courtesy of Cummins Engine Company, Inc.

- Advantages:
  - Standardized design with standardized service procedures
  - Less expensive to manufacture
  - Camshaft drive is relatively simple; does not rely on additional gears or long chains.
- Disadvantages:
  - Valve train reconditioning requires both block and head service.
  - Greater number of valve train components adds greater reciprocating weight.
  - Engine efficiency not as great as cam-in-head design.

768

b. **Cam-in-head (overhead cam)**—Engine design that mounts the cam over the valves, eliminating valve train components such as pushrods

Figure 3


Rocker assembly
Camshaft
Cylinder head
Intake and exhaust valves
Camshaft gear
Cylinder block
Piston

Courtesy of Detroit Diesel Corporation

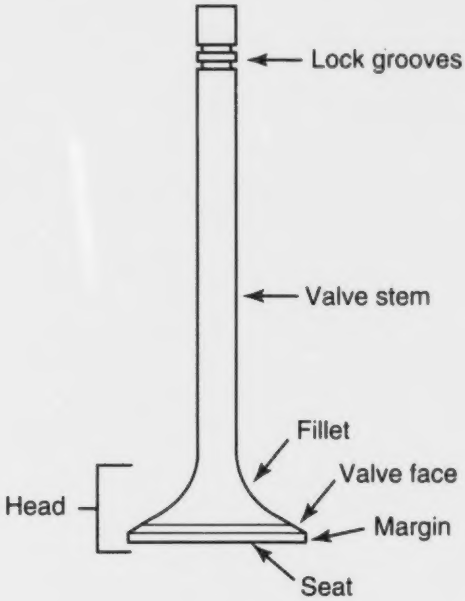
- Advantages:
  - Fewer valve train components; less reciprocating weight
  - Camshaft is easily accessible for service or adjustment.
  - Reconditioning is simplified; all components are housed in the cylinder head.
  - Crossflow design allows better airflow for improved scavenging and cylinder filling.
- Disadvantages:
  - More expensive to manufacture
  - More susceptible to wear

Information Sheet

Objective 4

Parts of a typical valve

Figure 4



Objective 5

Functions of valve parts

a. **Lock grooves**—Allow the locks/keepers to anchor the valve spring retainer to the valve stem

b. **Valve stem**—Supports the valve in the cylinder head

c. **Fillet**—Smoothes airflow around valve face and provides support for valve head

d. **Head**—Provides strength and rigidity for the valve face

e. **Margin**—Area between the face and the head that is reduced every time the valve face is reconditioned

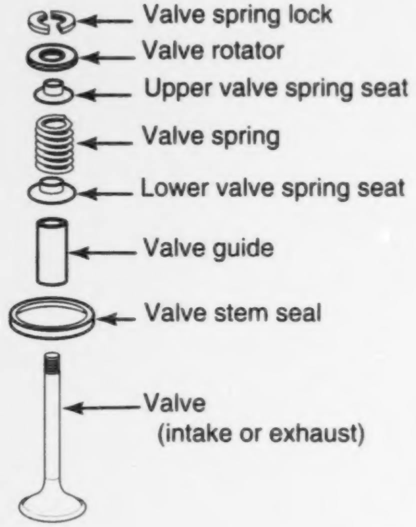
f. **Face**—Machined surface that contacts the valve seat and seals the port

770

Objective 6

Basic valve assembly components

Figure 5


Valve spring lock
Valve rotator
Upper valve spring seat
Valve spring
Lower valve spring seat
Valve guide
Valve stem seal
Valve
(intake or exhaust)

Objective 7

Functions of valve assembly components

a. **Valve**—Opens a port in the cylinder head, allowing fresh air to enter the cylinder or spent exhaust gases to leave it

b. **Valve rotator**—Turns the valve slightly each time it opens

c. **Valve seat**—Machined surface in the head that provides a sealing point for the valve face

d. **Valve spring**—Helical spring that keeps the valve closed

e. **Valve spring lock (keeper)**—Locks the valve spring retainer to the valve stem

f. **Valve spring retainer**—Provides an upper load surface for the valve spring and transmits spring pressure to the valve stem; usually found only on the exhaust valve

g. **Valve spring seat**—Replaceable metal disk that provides a wear surface between the valve spring and cylinder head

h. **Valve stem seal**—Prevents excess oil from entering the valve guide and flowing into the port or cylinder

Information Sheet

Objective 8

Operation of a valve rotator

a. During valve operation, the tappet/rocker arm applies pressure to the valve stem, compressing the valve spring.

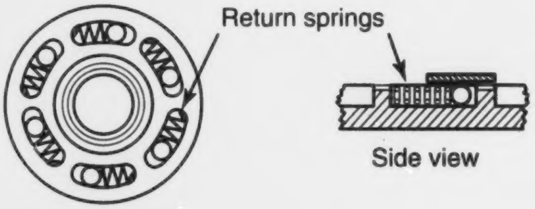
b. As the valve opens, valve spring load against the retainer increases, transferring pressure to the spring washer.

c. The compressed spring washer forces the balls to roll down an inclined plane, against the return springs.

d. This twisting force rotates the entire retainer assembly, which then rotates the valve.

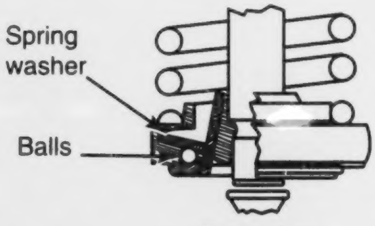
e. As the valve closes against the valve seat, pressure is removed from the spring washer, and the balls are pushed back to their starting point by the return springs.

Figure 6



Top view of cap

Side view



Front view
(cross section)

Reproduced by permission of John Deere Publishing, Deere & Company, Moline, IL. *Engines* © 1991. All rights reserved.

Objective 9

Common cylinder head problems

a. Warped block/manifold mating surface

b. Crack in the fire deck

c. Cracked valve seat

d. Flame erosion

Objective 10

Common valve/seat problems

a. Valve seat distortion

b. Deposits on valve or seat

c. Burned valve

d. Valve stem erosion

e. Heat fatigue

f. Worn valve guide

g. Breakage from impact or fatigue

Objective 11

Assignment Sheet 1—Locate and Label Intake and Exhaust Valves

Name ______________________________ Overall Rating __________

Date ______________________________

Evaluation Criteria	**Rating**
• Correct choice of manual and relevant repair section	______
• Valves correctly labeled per illustration	______

Basic Skills

Reading Writing

Introduction

Correctly identifying intake and exhaust valves allows accurate adjustment and troubleshooting. Valve adjustment and injector timing procedures always begin with the valves of #1 cylinder at a certain position. In order to tell the difference between TDC compression and TDC exhaust, you must know which valve is which.

Directions

For this assignment sheet, you will need one shop cylinder head (with or without valves installed) and the appropriate maintenance manual.

a. Notice the maintenance manual is divided into sections: Engine, Electrical System, Cooling System, etc. Turn to the engine section. At the front of this section will be the index. This lists all engine components covered by this manual. Find the section covering "cylinder head" and turn to it.

b. Orient the illustration provided in the manual with the cylinder head you are using.

Note: The camshaft (cam-in-head) or the push rods/push tubes (cam-in-block) will be on one side of the head. Use these to help you orient the illustration in the manual.

c Sketch an illustration in the space on the next page that shows your cylinder head configuration. Label the intake valves with "I" and the exhaust valves with "E."

d. Use the cylinder head you have been assigned to provide the information below.

- Cylinder head manufacturer ______________________________
- Cylinder head design (cam-in-block or cam-in-head?)____________

  ____

- Number of valves per cylinder______________________________

Objective 12

Job Sheet 1—Clean and Inspect a Cylinder Head

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Engine service manual used correctly	______
• Tools and precision measuring equipment used correctly	______
• Shop safety procedures followed	______
• Work area clean and well organized	______
• Job ticket completed correctly	______

Basic Skills

Reading Writing Mathematics Science Critical Thinking Employability

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, Equipment, and Materials

- Technician's common hand tools
- Appropriate service manual
- Job ticket or work order—one is included or use appropriate one provided at your facility
- Safety equipment
- Chain hoist or engine hoist
- Brass hammer
- Pry bar
- Torque wrench
- Straight-edge
- Feeler gauge set (.003" through .015")
- Gasket scraper
- Wire brush
- High pressure hot water washer
- Compressed air
- Shop towels
- Magnaflux® or similar dye product for checking cracks
- Cylinder head to be worked on
- Others—as recommended by instructor and equipment service manual

Caution: Valve springs are under pressure and wire brush bristles can come loose and cause eye injuries. Follow all shop safety procedures.

Procedure

☐ 1. Locate and follow the appropriate procedure in the service manual.

☐ 2. Complete the accompanying job ticket with all pertinent information.

776

☐ 3. Follow the engine manual for your specific cylinder head to perform the following procedures:

  ☐ a. Remove all remaining valve train components.

  ☐ b. Remove fuel injectors/injection nozzles.

  ☐ c. Remove any accessories still attached to the head.

☐ 4. Use a commercial engine cleaning solution and high pressure hot water washer to thoroughly clean the head.

☐ 5. Inspect the cylinder head.

  ☐ a. Using the gasket scraper and wire brush, clean the fire deck and all mating surfaces.

  ☐ b. Thoroughly inspect the mating surfaces of both head and block. Carefully check for the following:

  - Cracks in either the fire deck or valve seat areas
  - Nicks or dents to any gasket surface
  - Erosion of the fire deck surface due to compression leakage
  - Liner protrusion within specifications (if applicable)

  ☐ c. Examine the fuse plug(s) for signs of overheating. If a fuse plug has melted, carefully inspect the head for further heat damage.

  ☐ d. Check the water passages for lime/scale deposits and remove any soft plugs. Use a recommended solution and dip the head to remove any lime or scale.

Caution: Most dipping solutions are highly caustic! Wear a face shield and protective clothing and follow the supplier's directions carefully.

  ☐ e. Check the head for warpage.

  - Use the straight-edge and feeler gauge to check the fire deck edge for both transverse and longitudinal warpage. Check for longitudinal warpage in five places and transverse warpage in twelve places.

- Compare your findings with the engine manufacturer's published tolerances.

  Note: There will be slight warpage due to manufacturing procedures. This is not a cause for correction. Most engine manufacturers require that the fire deck (unclamped) be straight within .011 inches longitudinally and .003 inches transversely.

- If cylinder head warpage is within published tolerances, no further surface preparation is necessary. Obtain your instructor's initials in the space below and proceed to step #6.

- If head warpage exceeds tolerances, the decision must be made to either resurface or replace the head, depending on the manufacturer's recommendations. Consult with your instructor concerning this decision and obtain the instructor's initials in the space below.

  Instructor's initials _______________

☐ 6. Inspect cylinder head for cracks.

  ☐ a. Use compressed air to thoroughly dry the cylinder head.

  ☐ b. Using Magnaflux® or similar dye products, test the cylinder head for cracks as specified by the manufacturer. Pay special attention to the area around the valve seats.

  ☐ c. Clean the head thoroughly to remove all traces of dye or magnetic particles.

☐ 7. Install new soft plugs and a new fuse plug.

☐ 8. Pressure test the cylinder head if equipment is available.

Instructor's initials _______________

☐ 9. Turn in the job ticket when finished.

☐ 10. Clean work area and return tools and materials to proper storage.

Evaluator's Comments: ____

____

____

PARTS LIST

QTY.	PARTS/MATERIALS	PRICE	
TOTAL PARTS/MATERIALS			

SPECIFICATIONS CHECKED

School/Work Name ______________________

Address ______________________

Phone # ______________________

Date In ______________

Date Out ______________

JOB TICKET

Customer Name ______________________

Customer Address ______________________

Customer Phone # ______________________

Vehicle/Equip.	Make & Model	License #/Motor #/Serial #	Speedometer

Condition reported by customer/service requested: ______________________

Services/repairs made: ______________________

LABOR	

Customer Authorization

I, the undersigned, have reviewed the required service and parts estimates and authorize this maintenance to be performed with the understanding that I will be notified prior to the performance of any work that significantly exceeds those estimates in time or cost.

______________________ Date ______________

Technician ______________

Supervisor ______________

Objective 13

Job Sheet 2—Recondition a Cylinder Head

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	**Rating**
• Engine service manual used correctly	______
• Tools and precision measuring equipment used correctly	______
• Shop safety procedures followed	______
• Work area clean and well organized	______
• Job ticket completed correctly	______

Basic Skills

Reading Writing Mathematics Science Critical Thinking Employability

Introduction

Sealing the combustion chamber is critical to engine operating efficiency. Air, coolant, or compression leaks not only reduce engine output, they also cause expensive mechanical damage. Restoring the cylinder head to "like-new" condition helps ensure peak operating efficiency and minimizes the need for future repairs.

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Caution: Valve and seat reconditioning equipment produce airborne abrasives as well as metal chips. These can cause serious eye injuries. Be careful, and follow all shop safety procedures.

Tools, Equipment, and Materials

- Technician's common hand tools
- Appropriate service manual
- Job ticket or work order—one is included or use appropriate one provided at your facility
- Safety equipment
- Appropriate service manual
- Ball and hole gauge set
- Outside micrometer
- Dial test indicator with appropriate base
- Valve guide servicing equipment
- Valve/seat reconditioning equipment
- Valve spring compressor
- Valve stem seal installer
- Cylinder head to be worked on
- Others—as recommended by the instructor and equipment service manual

Job Sheet 2

Guidelines

a. This job sheet consists of the following sub-tasks:

- Measuring valve guide bores and replacing or reconditioning as needed
- Reconditioning/replacing valve seats
- Reconditioning/replacing valves
- Reassembling cylinder head components

b. To ensure the accuracy of the reconditioning process, the sub-tasks should be performed in the sequence listed. Your engine service manual will give you specific step-by-step instructions for each sub-task. As you complete each sub-task, your instructor will check your work for completeness and accuracy, and then initial this job sheet in the areas provided.

Procedure

Note: Cylinder head should be clean before starting this job sheet.

☐ 1. Locate and follow the appropriate procedure in the service manual.

☐ 2. Complete the worksheet and accompanying job ticket with all pertinent information.

☐ 3. Check valve guides for wear by measuring with a ball gauge and outside micrometer. Record your measurements in the worksheet that follows.

☐ 4. Compare your readings to the manufacturer's maximum allowable bore diameter.

☐ 5. Replace or recondition/repair any worn guides as outlined in service manual. Have your instructor inspect your work and initial below.

Instructor's initials _______________

☐ 6. Check valve seats for looseness by tapping them with a small ball peen hammer. A loose seat will sound different from a tight seat. If any loose seats are found, they must be replaced.

☐ 7. Refer to service manual for recommended valve seat data. Record in worksheet.

☐ 8. Recondition or replace valve seats as outlined in service manual.

☐ 9. Visually inspect the seat for cracks and width. Record in worksheet and compare to manufacturer's recommended width. Have your instructor inspect your work and initial below.

Instructor's initials ____________

☐ 10. Refer to service manual for recommended valve face data. Record in worksheet.

☐ 11. Recondition or replace valves as outlined in service manual. Have your instructor inspect your work and initial below.

Instructor's initials ____________

Caution: Always use recommended safety equipment (glasses, ear plugs, etc.) during valve refacing. Use extreme care when working with a grinding machine. Follow machine instructions.

☐ 12. Reassemble valve components as outlined in service manual.

☐ 13. When you have finished reassembling the cylinder head, have your instructor inspect the completed job and rate your work.

☐ 14. Turn in worksheet and job ticket when finished.

☐ 15. Clean work area and return tools and materials to proper storage.

Evaluator's Comments: ____

____

____

Job Sheet 2

Unit 7-B, Worksheet for Job Sheet 2

Name ______________________ Date __________ Attempt number ________

1. **Engine identification**

   a. Manufacturer ______________________________

   b. Model ______________________________

2. **Valve guides**

	Intake 1	**Intake 2**	**Exhaust 1**	**Exhaust 2**
Cylinder 1				
Cylinder 2				
Cylinder 3				
Cylinder 4				
Cylinder 5				
Cylinder 6				
Cylinder 7				
Cylinder 8				

Maximum allowable bore diameter: Intake __________ Exhaust __________

3. **Valve seats**

   a. Engine service manual data

   Seat angle: __________ Intake __________ Exhaust __________

   Seat width: __________ Intake __________ Exhaust __________

   Seat-to-guide alignment: Maximum __________

   Valve recess: __________

b. Visual inspection

Valve seat	OK	Cracked	Width
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			
16			

4. Valves

a. Face angle ______________________

b. Minimum allowable margin _____________

PARTS LIST

QTY.	PARTS/MATERIALS	PRICE	
TOTAL PARTS/MATERIALS			

SPECIFICATIONS CHECKED

School/Work Name ______________________

Address ______________________

Phone # ______________________

Date In ______________

Date Out ______________

JOB TICKET

Customer Name ______________________

Customer Address ______________________

Customer Phone # ______________________

Vehicle/Equip.	Make & Model	License #/Motor #/Serial #	Speedometer

Condition reported by customer/service requested: ______________________

____

Services/repairs made: ______________________

	LABOR	

Customer Authorization

I, the undersigned, have reviewed the required service and parts estimates and authorize this maintenance to be performed with the understanding that I will be notified prior to the performance of any work that significantly exceeds those estimates in time or cost.

______________________ Date ______________

Technician ______________

Supervisor ______________

786

787

Objective 14

Job Sheet 3—Install a Cylinder Head Assembly and Adjust Valves

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Engine service manual used correctly	______
• Tools and precision measuring equipment used correctly	______
• Shop safety procedures followed	______
• Work area clean and well organized	______
• Job ticket completed correctly	______

Basic Skills

Reading Writing Mathematics Critical Thinking Employability

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, Equipment, and Materials

- Technician's common hand tools
- Appropriate service manual
- Job ticket or work order—one is included or use appropriate one provided at your facility
- Safety equipment
- Chain hoist or engine hoist
- Head gasket
- Torque wrench
- Crankshaft turning tool
- Ratchet, 1/2″ drive
- Feeler gauge set (.005″ through .030″)
- Compressed air
- Shop towels
- Cylinder head assembly to be worked on
- Others—as recommended by the instructor and equipment service manua

Procedure

☐ 1. Locate and follow the appropriate procedure in the service manual.

☐ 2. Complete the accompanying job ticket with all pertinent information.

☐ 3. Clean block surface to remove dirt, grease, and gasket material.

☐ 4. Blow out all head bolt holes and wipe block surface clean.

☐ 5. Install head gasket onto block.

☐ 6. Make a final check of the engine cylinders to make sure no foreign objects are in them.

☐ 7. Install cylinder head and cylinder head bolts.

> **Caution:** The assembled cylinder head is very heavy and can easily crush fingers and hands. Keep your hands away from the area between the head and block mating surfaces as the head is lowered into place.

☐ 8. Install and torque head bolts as specified by manufacturer. Pay close attention to the torquing sequence for the head bolts.

> **Caution:** Failure to torque the bolts in the specified manner will result in damage to the head assembly as well as coolant and compression leaks.

Manufacturer's recommended torque and sequence ____________

____

Note: Head bolts need to be retorqued after engine is reassembled and warms up.

☐ 9. Have your instructor inspect the final torque sequence and initial below.

Instructor's initials ______________

Note: Check with your instructor before proceeding to valve adjustment. This procedure may be performed at another time as part of tune-up.

☐ 10. Adjust valves as specified by manufacturer. Be aware of the following points:

- It will be necessary to turn the crankshaft through two complete revolutions. For accuracy and safety, bar the engine over; do not use the starter motor.
- Do not adjust the valves and injector on the same cylinder at the same time. This will cause damage to the injector. The injector for a given cylinder is adjusted 180 crankshaft degrees after that cylinder's valves are adjusted.

☐ 11. After you have completed the valve and injector adjustments, have your instructor inspect your work and initial below.

Instructor's initials ____________

☐ 12. Turn in job ticket when finished.

☐ 13. Clean work area and return tools and materials to proper storage.

Evaluator's Comments: ________________________________

____

____

PARTS LIST

QTY.	PARTS/MATERIALS	PRICE	
TOTAL PARTS/MATERIALS			

SPECIFICATIONS CHECKED

School/Work Name ______________________

Address ______________________

Phone # ______________________

Date In ______________

Date Out ______________

JOB TICKET

Customer Name ______________________

Customer Address ______________________

Customer Phone # ______________________

Vehicle/Equip.	Make & Model	License #/Motor #/Serial #	Speedometer

Condition reported by customer/service requested: ______________________

Services/repairs made: ______________________

	LABOR	

Customer Authorization

I, the undersigned, have reviewed the required service and parts estimates and authorize this maintenance to be performed with the understanding that I will be notified prior to the performance of any work that significantly exceeds those estimates in time or cost.

______________________ Date ______________

Technician ______________

Supervisor ______________

Unit 8-B Air Induction and Exhaust Systems

Unit Contents

Student Components

Student Page

Objective Sheet 8B–3

Information Sheet 8B–5

Job Sheets

1—Inspect and Test Air Induction System 8B–13
2—Inspect and Service Turbo/Supercharger and Related Components 8B–17
3—Clean and Test Jacket Water Intercooler 8B–21
4—Clean and Test Air-to-Air Intercooler 8B–25
5—Inspect and Test Exhaust System 8B–29
6—Inspect Starting Preheater Controls 8B–33
7—Test Starting Fluid System and Controls 8B–37

Unit 8-B Air Induction and Exhaust Systems

Objective Sheet

Unit Objective

After completing this unit, the student should be able to identify and service basic air induction and exhaust components including turbochargers and superchargers. The student should demonstrate these competencies by completing the job sheets and by scoring a minimum of 85 percent on the written test.

Specific Objectives

After completing this unit, the student should be able to:

1. Match terms related to air induction and exhaust with their definitions.
2. Label the basic air induction components.
3. Match air induction components with their functions.
4. Identify the types of air induction systems.
5. Label the main parts of a turbocharger.
6. List starting aid devices.
7. Identify basic exhaust system components.
8. Match exhaust system components with their functions.
9. Arrange in order the sequence of operation for an air induction and exhaust system.
10. Complete statements concerning the scavenging process for two-stroke and four-stroke diesel engines.
11. Distinguish between agricultural/industrial and motor vehicle exhaust systems.
12. Identify the parts of a typical catalytic converter.
13. Complete statements concerning the operation of a catalytic converter.
14. Inspect and test air induction system. (Job Sheet 1)
15. Inspect and service turbo/supercharger and related components. (Job Sheet 2)
16. Clean and test jacket water intercooler. (Job Sheet 3)
17. Clean and test air-to-air intercooler. (Job Sheet 4)
18. Inspect and test exhaust system. (Job Sheet 5)
19. Inspect starting preheater controls. (Job Sheet 6)
20. Test starting fluid system and controls. (Job Sheet 7)

Information Sheet

Objective 1

Terms and definitions

a. **Air restriction indicator**—Indicates increasing restriction in the induction system due to a dirty filter element or a damaged component

b. **Blower**—Mechanically-driven supercharger

c. **Monolith**—Catalytic converter design using a honeycomb-style core

d. **Naturally-aspirated**—Engine that does not use superchargers or turbochargers

e. **Scavenging**—Using fresh intake air to evacuate burnt exhaust gases from the cylinder

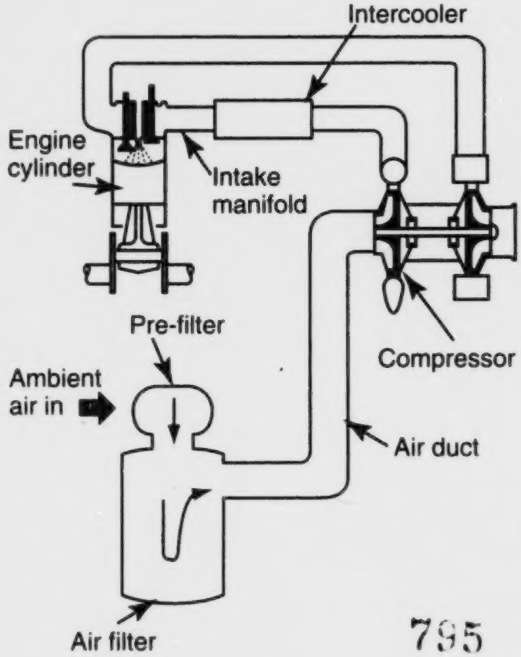
f. **Supercharging**—Forcing air into the cylinders above atmospheric pressure; usually applies to devices that have a direct mechanical connection to the engine

g. **Turbocharging**—Using an exhaust-driven compressor unit to force air into the cylinders; applies to devices (turbochargers) that have no direct mechanical connection to the engine

Objective 2

Basic air induction components

Figure 1



Information Sheet

Objective 3

Functions of air induction components

a. **Prefilter (or precleaner)**—Removes large dust particles from the intake air before it enters the air filter

b. **Air filter**--Removes grit and fine dust particles; provides the engine with the required volume of clean air

c. **Compressor**—Pressurizes the air entering the engine; provides greater cylinder filling

d. **Intercooler (or aftercooler)**—Cools the compressed air before sending it into the intake manifold; provides a denser air charge which improves combustion

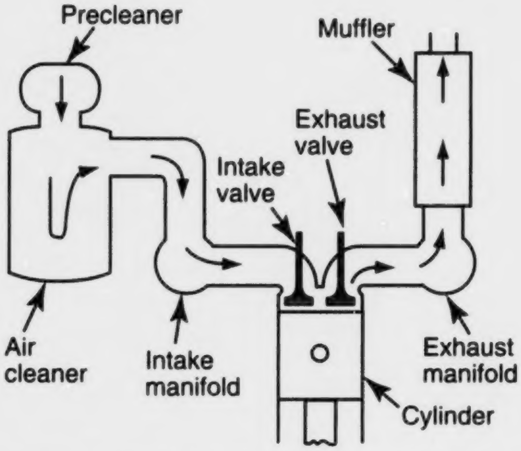
e. **Intake manifold**—Channels the air to the individual cylinder intake ports

Objective 4

Types of air induction systems

a. Normally aspirated

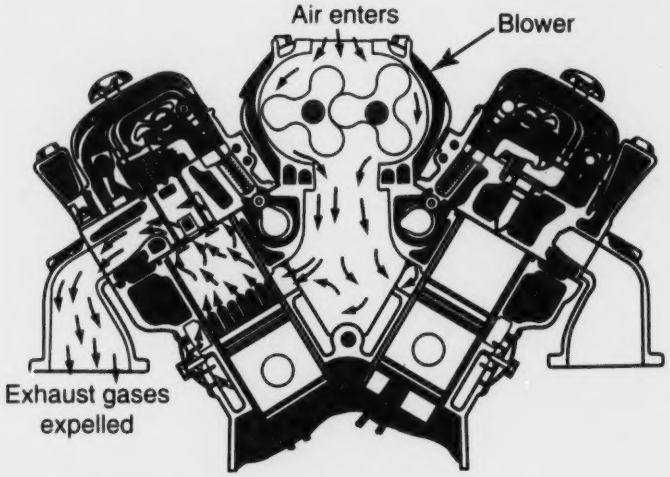
Figure 2


Precleaner
Muffler
Exhaust valve
Intake valve
Air cleaner
Intake manifold
Exhaust manifold
Cylinder

Reproduced by permission of John Deere Publishing, Deere & Company, Moline, IL. *Engines* © 1991. All rights reserved.

b. Supercharged

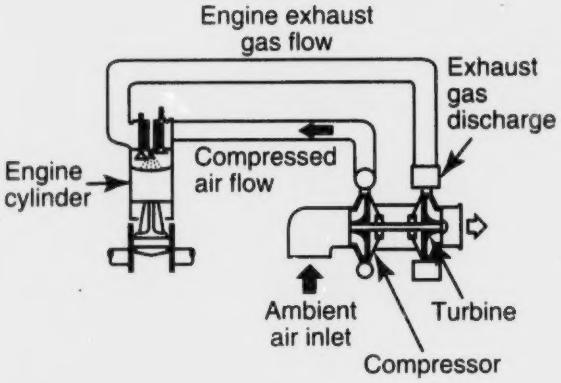
Figure 3


Air enters
Blower
Exhaust gases expelled

Courtesy of Detroit Diesel Corporation

c. Turbocharged

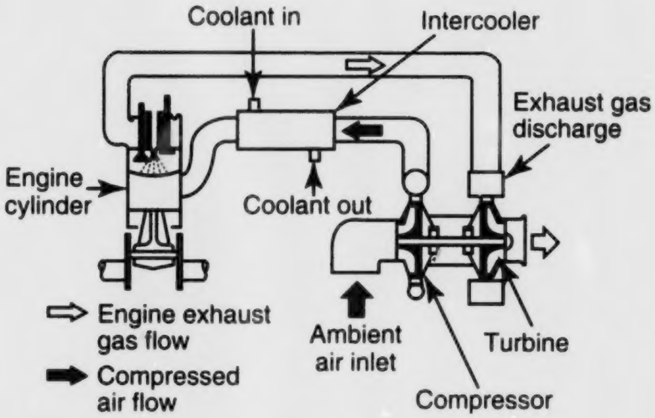
Figure 4


Engine exhaust gas flow
Exhaust gas discharge
Compressed air flow
Engine cylinder
Ambient air inlet
Turbine
Compressor

Courtesy of Detroit Diesel Corporation

d. Turbocharged and intercooled

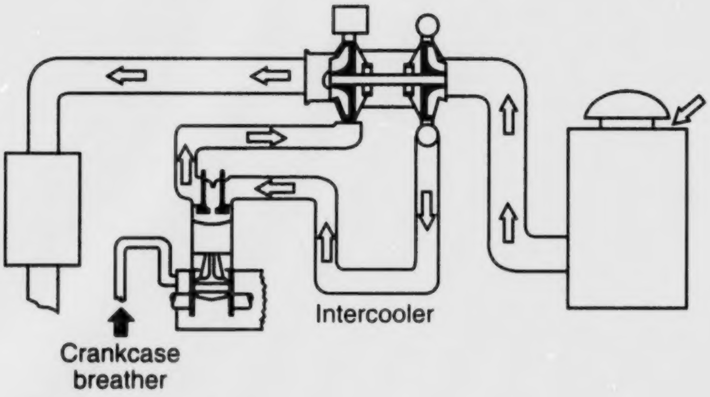
Figure 5


Coolant in
Intercooler
Exhaust gas discharge
Engine cylinder
Coolant out
⇨ Engine exhaust gas flow
➡ Compressed air flow
Ambient air inlet
Turbine
Compressor

Courtesy of Detroit Diesel Corporation

e. Air-to-air charger aftercooler or intercooler

Figure 6

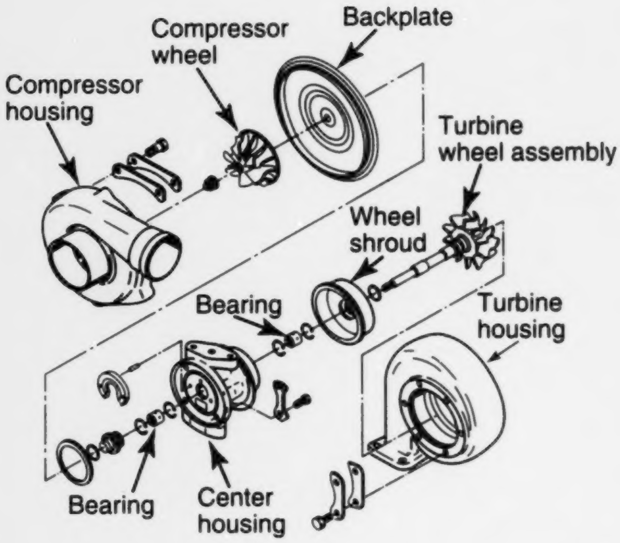

Intercooler
Crankcase breather

Courtesy of Detroit Diesel Corporation

Objective 5

Main parts of a turbocharger

Figure 7


Compressor wheel
Backplate
Compressor housing
Turbine wheel assembly
Wheel shroud
Bearing
Turbine housing
Bearing
Center housing

Courtesy of Detroit Diesel Corporation

Objective 6

Starting aid devices

a. Block heaters/preheaters

b. Glow plugs

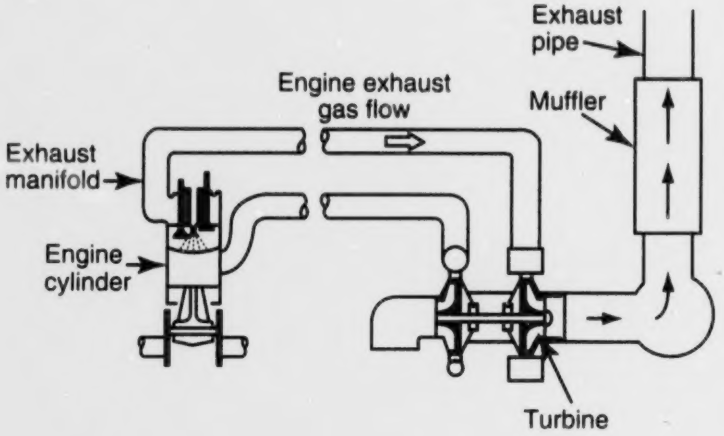
c. Starting fluid injection

Information Sheet

Objective 7

Basic exhaust system components

Figure 8



Objective 8

Functions of exhaust system components

a. **Exhaust manifold**—Routes hot gases from the exhaust ports to the inlet side of the turbocharger turbine

b. **Exhaust pipe**—Channels exhaust gases from the discharge side of the turbocharger turbine to the muffler (if equipped) or to the atmosphere

c. **Muffler**—Absorbs and redirects the sound waves from the exhaust gases; greatly reduces exhaust noise

d. **Turbine**—Uses exhaust gas heat and pressure to rotate and drive the compressor on the other side of the turbocharger

Objective 9

Operation of an induction and exhaust system

a. Hot, expanding exhaust gases leave the exhaust port and are channeled through the exhaust manifold to the turbine side of the turbocharger. These gases strike the turbine blades, causing them to spin (70,000-145,000 rpm).

b. The exhaust flow exits the turbine housing and flows through the muffler where it is quieted.

c. Exhaust is then sent to the tailpipe or exhaust stack. The spinning turbine is connected by a shaft to the compressor, which is also turning (70,000-145,000 rpm).

d. The compressor pulls in filtered air and compresses it.

e. The compressed (and heated) air is sent to the intercooler, where it is cooled and condensed.

f. The dense, compressed air flows from the intercooler, through the intake manifold, to each cylinder intake port.

g. Inside the cylinder, the air is mixed with fuel, burned, and then pushed out the exhaust port.

Objective 10

Diesel engine scavenging

a. **Two-stroke engines**

- As the piston nears the end of the power stroke, the exhaust valves open, allowing exhaust gases to begin leaving the cylinder.
- As the piston continues to move downward, the inlet ports are uncovered.
- Compressed air from the blower enters the cylinder through the inlet ports, driving out the remaining exhaust gas.

b. **Four-stroke engines**

- At the end of the power stroke, just before the piston reaches BDC, the exhaust valves open.
- The piston rises, pushing the exhaust gases out of the cylinder.
- Just before the piston reaches TDC, the intake valves open. Because of valve overlap, the exhaust valves are still open. This allows fresh compressed air to enter the cylinder, driving out the remaining exhaust gases.

Objective 11

Exhaust systems

a. **Motor vehicle**

- Effective mufflers are required to reduce sound levels to acceptable limits.
- Tailpipes must route exhaust gases away from the underside of the vehicle to prevent trapping carbon monoxide.

b. **Agricultural/Industrial**

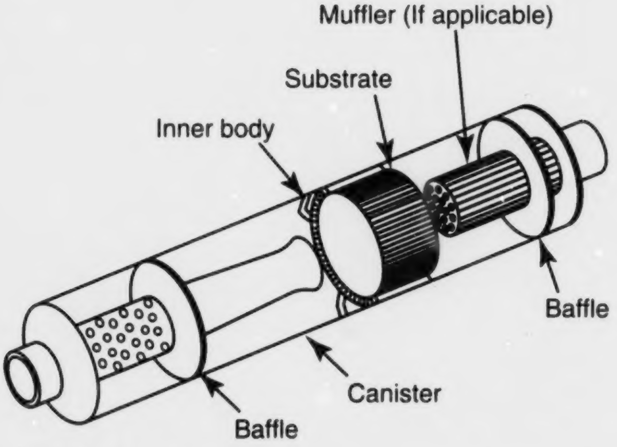
- Sound dampening is not as critical in the middle of farm land as it is on a city street; some turbocharged engines do not use mufflers at all.
- Exhaust pipes are typically used to carry smoke and noise away from the immediate area of the engine.

Information Sheet

Objective 12

Parts of a typical catalytic converter

Figure 9



Courtesy of Cummins Engine Company, Inc.

Objective 13

Operation of a catalytic converter

a. Exhaust gas enters the converter and passes through the reducing catalyst. This reduces the NO_x (oxides of nitrogen) level.

b. The exhaust gas next passes through the oxidizing part of the converter. This area converts the HC (hydrocarbons) and CO (carbon monoxide) into H_2O and CO_2.

c. As this reduction reaction takes place, the converter generates tremendous amounts of heat. Most catalytic converters operate around 1500°F.

d. The exhaust gas leaves the catalytic converter as harmless water vapor, carbon dioxide, and low-level NO_x.

Objective 14

Job Sheet 1—Inspect and Test Air Induction System

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Correct procedures identified for assigned vehicle	______
• Procedures completed correctly	______
• Proper tools used correctly	______
• Safety precautions observed	______
• Installed equipment functions correctly	______
• Serviced equipment meets specifications	______
• Clean-up and follow-up actions adequate	______

Basic Skills

Reading Writing Mathematics Science Critical Thinking Employability

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, Equipment, and Materials

- Technician's common hand tools
- Appropriate service manual
- Job ticket or work order—one is included or use appropriate one provided at your facility
- Safety equipment
- Manometer
- Flashlight
- Handheld extension mirror
- Dynamometer
- Engine to be worked on
- Others—as recommended by instructor and equipment service manual

Guidelines

☐ 1. Install the manometer in a straight section of tubing as close to the turbocharger as possible. This will be used to measure inlet restriction.

☐ 2. Ensure that the air filter has been cleaned/serviced.

Procedure

☐ 1. Locate and follow the appropriate procedure in the service manual.

☐ 2. Complete the accompanying job ticket with all pertinent information.

☐ 3. Set parking brake, remove ignition key, and chock wheels.

☐ 4. Visually inspect all metal ductwork for dents or distortion.

☐ 5. Physically compress flexible rubber couplings, while watching for signs of cracking or deterioration.

☐ 6. Check the tightness of all hose clamps.

☐ 7. Connect the manometer according to the manufacturer's instructions. Ensure that the fitting is in a straight section of tubing as close to the turbocharger inlet as possible and at a right angle to the airflow.

☐ 8. Start the engine and operate at required load and speed.

☐ 9. Measure pressure drop at the turbocharger inlet; record the reading below.

Measured inlet pressure drop ______________________

Manufacturer's maximum allowable pressure drop:

a. Used filter element ______________________

b. New filter element ______________________

☐ 10. Remove the load, allow the engine to idle until it cools, then shut it down.

☐ 11. Remove the manometer from the turbocharger inlet, and reconnect it to the inlet manifold.

Note: Most engine manufacturers provide a removable fitting for testing inlet manifold pressure.

☐ 12. Start the engine and operate it at the required load and speed.

☐ 13. Measure the inlet boost pressure; record the reading below.

Measured inlet manifold boost pressure ______________________

Manufacturer's recommended boost pressure ______________________

☐ 14. Remove the load, allow the engine to idle until it cools, then shut it down.

☐ 15. Remove test equipment.

☐ 16. Turn in job ticket when finished.

☐ 17. Clean work area and return tools and materials to proper storage.

Evaluator's Comments: ____________________

____

____

Job Sheet 1

PARTS LIST

QTY.	PARTS/MATERIALS	PRICE	
TOTAL PARTS/MATERIALS			

SPECIFICATIONS CHECKED

School/Work Name ____________________

Address ____________________

Phone # ____________________

Date In ____________

Date Out ____________

JOB TICKET

Customer Name ____________________

Customer Address ____________________

Customer Phone # ____________________

Vehicle/Equip.	Make & Model	License #/Motor #/Serial #	Speedometer

Condition reported by customer/service requested: ____________________

Services/repairs made: ____________________

LABOR	

Customer Authorization

I, the undersigned, have reviewed the required service and parts estimates and authorize this maintenance to be performed with the understanding that I will be notified prior to the performance of any work that significantly exceeds those estimates in time or cost.

____________________ Date ____________

Technician ____________

Supervisor ____________

Objective 15

Job Sheet 2—Inspect and Service Turbo/Supercharger and Related Components

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Correct procedures identified for assigned vehicle	______
• Procedures completed correctly	______
• Proper tools used correctly	______
• Safety precautions observed	______
• Installed equipment functions correctly	______
• Serviced equipment meets specifications	______
• Clean-up and follow-up actions adequate	______

Basic Skills

Reading Writing Mathematics Critical Thinking Employability

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, Equipment, and Materials

- Technician's common hand tools
- Appropriate service manual
- Job ticket or work order—one is included or use appropriate one provided at your facility
- Safety equipment
- Test equipment as required by engine manufacturer
- Torque wrench
- Dial test indicator
- Gaskets, seals, and parts as required
- Air drill and sanding discs
- Engine to be worked on
- Others—as recommended by instructor and equipment service manual

Guidelines

☐ 1. When running the engine without air intake ductwork attached, be sure to install an intake guard over the turbocharger inlet.

☐ 2. Prelube the turbocharger with clean engine oil before attaching the oil supply line.

☐ 3. Dispose of waste oil in accordance with EPA guidelines.

☐ 4. Place all oily shop towels in approved airtight storage containers.

Procedure

☐ 1. Locate and follow the appropriate procedure in the service manual.

☐ 2. Complete the accompanying job ticket with all pertinent information.

☐ 3. Set parking brake, remove ignition key, and chock wheels.

☐ 4. Disconnect oil drain and supply lines.

☐ 5. Disconnect the intake air duct and the exhaust pipe.

☐ 6. Remove the turbocharger.

☐ 7. Clean the manifold gasket surface with the abrasive disk. Then visually inspect for cracks or erosion.

☐ 8. Visually inspect the turbocharger air outlet for the presence of oil. This will be indicated by oil dripping from the outlet. The following could be causes for excess leakage:

  ☐ a. Restricted air cleaner

  ☐ b. Oil drain line restricted or improperly routed

  ☐ c. High crankcase pressure

☐ 9. Visually inspect the turbine and compressor wheels for nicks or bent blades.

☐ 10. Check turbocharger shaft axial end play.

  ☐ a. Mount a magnetic base dial indicator on the turbine inlet.

  ☐ b Push the turbocharger shaft all the way in one direction. Zero the dial test indicator.

  ☐ c. Push the shaft all the way in the opposite direction. Record the reading on the dial test indicator below.

  Indicated axial end play ______________________

  Recommended axial end play ____________________

☐ 11. Check turbocharger shaft radial clearance.

  ☐ a. Grasp the turbocharger shaft and attempt to move the turbine wheels against the housing. If the turbine or compressor wheels contact the housing, the shaft bearings are worn out.

- ☐ b. Worn out shaft bearings require that the turbocharger be either rebuilt or replaced. Your instructor will make this decision.

☐ 12. Install the turbocharger.

☐ 13. Reconnect the oil drain line.

☐ 14. Before connecting the oil supply line, pour clean motor oil into the turbocharger oil supply line fitting.

☐ 15. Install intake air duct and exhaust pipe.

☐ 16. Start the engine and check for proper operation.

☐ 17. Turn in job ticket when finished.

☐ 18. Clean work area and return tools and materials to proper storage.

Evaluator's Comments: ______________________________

____

____

Job Sheet 2

PARTS LIST

QTY.	PARTS/MATERIALS	PRICE	
TOTAL PARTS/MATERIALS			

SPECIFICATIONS CHECKED

School/Work Name ____________________

Address ____________________

Phone # ____________________

Date In __________

Date Out __________

JOB TICKET

Customer Name ____________________

Customer Address ____________________

Customer Phone # ____________________

Vehicle/Equip.	Make & Model	License #/Motor #/Serial #	Speedometer

Condition reported by customer/service requested: ____________________

Services/repairs made: ____________________

LABOR	

Customer Authorization

I, the undersigned, have reviewed the required service and parts estimates and authorize this maintenance to be performed with the understanding that I will be notified prior to the performance of any work that significantly exceeds those estimates in time or cost.

____________________ Date __________

Technician __________

Supervisor __________

Objective 16

Job Sheet 3—Clean and Test Jacket Water Intercooler

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Correct procedures identified for assigned vehicle	______
• Procedures completed correctly	______
• Proper tools used correctly	______
• Safety precautions observed	______
• Installed equipment functions correctly	______
• Serviced equipment meets specifications	______
• Clean-up and follow-up actions adequate	______

Basic Skills

Reading Writing Mathematics Science Critical Thinking Employability

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, Equipment, and Materials

- Technician's common hand tools
- Appropriate service manual
- Job ticket or work order—one is included or use appropriate one provided at your facility
- Safety equipment
- Test equipment as required by engine manufacturer
- Compressed air
- Water tank
- Soap and water solution
- Manometer or magnahelic gauge
- Vegetable oil
- Engine to be worked on
- Others—as recommended by instructor and equipment service manual

Guidelines

☐ 1. To avoid component damage during testing, limit air pressure to 25 psi.

☐ 2. Install the manometer in a straight section of tubing as close to the turbocharger as possible.

☐ 3. Lubricate O-rings with vegetable oil, not engine oil.

Job Sheet 3

Procedure

☐ 1. Locate and follow the appropriate procedure in the service manual.

☐ 2. Complete the accompanying job ticket with all pertinent information.

☐ 3. Set parking brake, remove ignition key, and chock wheels.

☐ 4. Remove aftercooler/intercooler from vehicle.

☐ 5. Clean all gasket surfaces (as required).

☐ 6. Visually inspect the unit for cracks or damage.

☐ 7. Test for leaks by submerging the intercooler in a water tank and pressurizing it with compressed air.

Note: To avoid component damage during testing, limit air pressure to 25 psi.

☐ 8. Visually inspect for leaks. Note any on the job sheet and report to the instructor.

☐ 9. Remove the intercooler from the water tank and dry it with compressed air.

☐ 10. Reinstall on the vehicle.

☐ 11. Connect the manometer to the turbocharger compressor outlet according to the manufacturer's instructions. Ensure that the fitting is in a straight section of tubing as close to the turbocharger as possible and at a right angle to the airflow.

☐ 12. Start the engine and operate it at the required load and speed.

☐ 13. Measure the boost pressure; record the reading below.

Measured compressor outlet boost pressure ____________________

☐ 14. Remove the load, allow the engine to idle until it cools, then shut it down.

☐ 15. Remove the manometer from the turbocharger compressor outlet, and reconnect it to the inlet manifold.

Note: Most engine manufacturers provide a removable fitting for testing inlet manifold pressure.

☐ 16. Start the engine and operate it at the required load and speed.

☐ 17. Measure the inlet manifold boost pressure; record the reading below.

Measured inlet manifold boost pressure ____________________

☐ 18. Subtract your reading in step 17 from your reading in step 13. This is the pressure drop across the intercooler; record it below.

Measured pressure drop across intercooler ____________________

Manufacturer's recommended pressure drop ____________________

☐ 19. Remove the load, allow the engine to idle until it cools, then shut it down.

☐ 20. Remove test equipment.

☐ 21. Turn in job ticket when finished.

☐ 22. Clean work area and return tools and materials to proper storage.

Evaluator's Comments: ____

____

____

Job Sheet 3

PARTS LIST

QTY.	PARTS/MATERIALS	PRICE	
TOTAL PARTS/MATERIALS			

SPECIFICATIONS CHECKED

School/Work Name ____________________
Address ____________________
Phone # ____________________

Date In ____________
Date Out ____________

JOB TICKET

Customer Name ____________________
Customer Address ____________________
Customer Phone # ____________________

Vehicle/Equip.	Make & Model	License #/Motor #/Serial #	Speedometer

Condition reported by customer/service requested: ____________________

Services/repairs made: ____________________

LABOR	

Customer Authorization

I, the undersigned, have reviewed the required service and parts estimates and authorize this maintenance to be performed with the understanding that I will be notified prior to the performance of any work that significantly exceeds those estimates in time or cost.

____________________ Date ____________

Technician ____________
Supervisor ____________

Objective 17

Job Sheet 4—Clean and Test Air-to-Air Intercooler

Name ____________________ Attempt Number ________

Date ____________________ Overall Rating ________

Evaluation Criteria	Rating
• Correct procedures identified for assigned vehicle	______
• Procedures completed correctly	______
• Proper tools used correctly	______
• Safety precautions observed	______
• Installed equipment functions correctly	______
• Serviced equipment meets specifications	______
• Clean-up and follow-up actions adequate	______

Basic Skills

Reading Writing Mathematics Science Critical Thinking Employability

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, Equipment, and Materials

- Technician's common hand tools
- Appropriate service manual
- Job ticket or work order—one is included or use appropriate one provided at your facility
- Safety equipment
- Compressed air
- Soap and water solution
- Manometer or magnahelic gauge
- Vegetable oil
- Engine to be worked on
- Others—as recommended by instructor and equipment service manual

Guidelines

☐ 1. To avoid component damage during testing, limit air pressure to 25 psi.

☐ 2. Install the manometer in a straight section of tubing as close to the turbocharger as possible.

☐ 3. Lubricate O-rings with vegetable oil, not engine oil.

Procedure

☐ 1. Locate and follow the appropriate procedure in the service manual.

☐ 2. Complete the accompanying job ticket with all pertinent information.

☐ 3. Set parking brake, remove ignition key, and chock wheels.

☐ 4. Remove aftercooler/intercooler from vehicle.

☐ 5. Clean all hose connecting points and gasket surfaces (as required).

☐ 6. Visually inspect the intercooler for cracks or damage.

☐ 7. Install plugs in the intercooler inlet and outlet.

☐ 8. Pressurize the intercooler with compressed air.

Note: To avoid component damage during testing, limit air pressure to 25 psi.

☐ 9. Spray the intercooler with the soap and water solution. Observe any bubbles; these indicate leaks. Note this on your job ticket.

☐ 10. Wash the soap and water solution off the intercooler and dry with compressed air.

☐ 11. Remove the plugs.

☐ 12. Reinstall the intercooler on the vehicle.

☐ 13. Connect the manometer to the turbocharger compressor outlet according to the manufacturer's instructions. Ensure that the fitting is in a straight section of tubing as close to the turbocharger as possible and at a right angle to the airflow.

☐ 14. Start the engine and operate it at the required load and speed.

☐ 15. Measure the boost pressure; record the reading below.

Measured compressor outlet boost pressure ____________________

☐ 16. Remove the load, allow the engine to idle until it cools, then shut it down.

☐ 17. Remove the manometer from the turbocharger compressor outlet, and reconnect it to the inlet manifold.

Note: Most engine manufacturers provide a removable fitting for testing inlet manifold pressure.

☐ 18. Start the engine and operate it at the required load and speed.

☐ 19. Measure the inlet manifold boost pressure; record the reading below.

Measured inlet manifold boost pressure ____________________

☐ 20. Subtract your reading in step 19 from your reading in step 15. This is the pressure drop across the intercooler; record it below.

Measured pressure drop across intercooler ____________________

Manufacturer's recommended pressure drop ____________________

☐ 21. Remove the load, allow the engine to idle until it cools, then shut it down.

☐ 22. Remove test equipment.

☐ 23. Turn in job ticket when finished.

☐ 24. Clean work area and return tools and materials to proper storage.

Evaluator's Comments: ____

____

____

PARTS LIST

QTY.	PARTS/MATERIALS	PRICE	
TOTAL PARTS/MATERIALS			

SPECIFICATIONS CHECKED

School/Work Name ______

Address ______

Phone # ______

Date In ______

Date Out ______

JOB TICKET

Customer Name ______

Customer Address ______

Customer Phone # ______

Vehicle/Equip.	Make & Model	License #/Motor #/Serial #	Speedometer

Condition reported by customer/service requested: ______

Services/repairs made:	LABOR	

Customer Authorization

I, the undersigned, have reviewed the required service and parts estimates and authorize this maintenance to be performed with the understanding that I will be notified prior to the performance of any work that significantly exceeds those estimates in time or cost.

______ Date ______

Technician ______

Supervisor ______

Objective 18

Job Sheet 5—Inspect and Test Exhaust System

Name ____________________ Attempt Number ________

Date ____________________ Overall Rating ________

Evaluation Criteria	Rating
• Correct procedures identified for assigned vehicle	______
• Procedures completed correctly	______
• Proper tools used correctly	______
• Safety precautions observed	______
• Installed equipment functions correctly	______
• Serviced equipment meets specifications	______
• Clean-up and follow-up actions adequate	______

Basic Skills

Reading Writing Mathematics Science Critical Thinking Employability

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, Equipment, and Materials

- Technician's common hand tools
- Appropriate service manual
- Job ticket or work order—one is included or use appropriate one provided at your facility
- Safety equipment
- Manometer or magnahelic gauge
- Engine to be worked on
- Others—as recommended by instructor and equipment service manual

Guidelines

☐ 1. When replacing threaded plugs in the exhaust system, coat the threads with a high temperature sealant such as Permatex Ultra Copper Sealant, Silkolene 762, or equivalent.

☐ 2. Install the manometer/magnahelic gauge in the first bend of tubing out of the turbocharger turbine outlet.

Procedure

☐ 1. Locate and follow the appropriate procedure in the service manual.

☐ 2. Complete the accompanying job ticket with all pertinent information.

☐ 3. Set parking brake, remove ignition key, and chock wheels.

☐ 4. Visually inspect exhaust system for signs of cracks, leaks, or dents. Pay particular attention to manifold bolt clamping areas.

☐ 5. Attach the manometer/magnahelic gauge to the turbocharger exhaust outlet elbow.

Note: Most engine manufacturers provide a removable fitting for testing turbine outlet pressure.

☐ 6. Start and run the engine at recommended speed. Observe the manometer/ magnahelic gauge; record the reading below.

Measured exhaust system back pressure ____________

☐ 7. Compare manometer reading with OEM specifications for exhaust system back pressure.

Manufacturer's recommended back pressure ____________

☐ 8. Turn in job ticket when finished.

☐ 9. Clean work area and return tools and materials to proper storage.

Evaluator's Comments: ____

____

____

824

PARTS LIST

QTY.	PARTS/MATERIALS	PRICE	
TOTAL PARTS/MATERIALS			

SPECIFICATIONS CHECKED

School/Work Name ______________________

Address ______________________

Phone # ______________________

Date In ____________

Date Out ____________

JOB TICKET

Customer Name ______________________

Customer Address ______________________

Customer Phone # ______________________

Vehicle/Equip.	Make & Model	License #/Motor #/Serial #	Speedometer

Condition reported by customer/service requested: ______________________

Services/repairs made: ______________________

LABOR	

Customer Authorization

I, the undersigned, have reviewed the required service and parts estimates and authorize this maintenance to be performed with the understanding that I will be notified prior to the performance of any work that significantly exceeds those estimates in time or cost.

______________________ Date ____________

Technician ____________

Supervisor ____________

Objective 19

Job Sheet 6—Inspect Starting Preheater Controls

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Correct procedures identified for assigned vehicle	______
• Procedures completed correctly	______
• Proper tools used correctly	______
• Safety precautions observed	______
• Installed equipment functions correctly	______
• Serviced equipment meets specifications	______
• Clean-up and follow-up actions adequate	______

Basic Skills

Reading Writing Critical Thinking Employability

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, Equipment, and Materials

- Technician's common hand tools
- Appropriate service manual
- Job ticket or work order—one is included or use appropriate one provided at your facility
- Safety equipment
- Multimeter
- Engine to be worked on
- Others—as recommended by instructor and equipment service manual

Procedure

☐ 1. Locate and follow the appropriate procedure in the service manual.

☐ 2. Complete the accompanying job ticket with all pertinent information.

☐ 3. Set parking brake and chock wheels.

☐ 4. Turn ignition on and energize preheater system. Observe indicator light operation.

☐ 5. Crank engine and note if engine starts easily.

☐ 6. If indicator light fails to illuminate, or if engine starts with difficulty or not at all, note this on the job ticket.

☐ 7. Check electrical temperature sensors and relays for correct operation as described by the manufacturer.

☐ 8. Turn in job ticket when finished.

☐ 9. Clean work area and return tools and materials to proper storage.

Evaluator's Comments: ______________________________

____

____

PARTS LIST

QTY.	PARTS/MATERIALS	PRICE	
TOTAL PARTS/MATERIALS			

SPECIFICATIONS CHECKED

School/Work Name ______________________

Address ______________________

Phone # ______________________

Date In ____________

Date Out ____________

JOB TICKET

Customer Name ______________________

Customer Address ______________________

Customer Phone # ______________________

Vehicle/Equip.	Make & Model	License #/Motor #/Serial #	Speedometer

Condition reported by customer/service requested: ______________________

Services/repairs made: ______________________

LABOR	

Customer Authorization

I, the undersigned, have reviewed the required service and parts estimates and authorize this maintenance to be performed with the understanding that I will be notified prior to the performance of any work that significantly exceeds those estimates in time or cost.

______________________ Date ____________

Technician ____________

Supervisor ____________

Objective 20

Job Sheet 7—Test Starting Fluid System and Controls

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Correct procedures identified for assigned vehicle	______
• Procedures completed correctly	______
• Proper tools used correctly	______
• Safety precautions observed	______
• Installed equipment functions correctly	______
• Serviced equipment meets specifications	______
• Clean-up and follow-up actions adequate	______

Basic Skills

Reading Writing Critical Thinking Employability

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, Equipment, and Materials

- Technician's common hand tools
- Appropriate service manual
- Job ticket or work order—one is included or use appropriate one provided at your facility
- Safety equipment
- Test equipment/harnesses as required by engine manufacturer
- Engine to be worked on
- Others—as recommended by instructor and equipment service manual

Guidelines

☐ 1. Starting fluid is both poisonous and flammable. Follow special precautions.

  a. Do not breathe the vapors. Work only in well ventilated areas.

  b. If starting fluid contacts the skin, wash immediately.

  c. Do not handle starting fluid around open flames, lit cigarettes, etc.

☐ 2. Ensure that the starting fluid containers are correctly installed.

☐ 3. Place all oily shop towels in approved airtight storage containers.

Job Sheet 7

Procedure

☐ 1. Locate and follow the appropriate procedure in the service manual.

☐ 2. Complete the accompanying job ticket with all pertinent information.

☐ 3. Set parking brake, remove ignition key, and chock wheels.

☐ 4. Remove the starting fluid nozzle(s) from the intake manifold plenums. Place the nozzles in a jar to catch the starting fluid.

☐ 5. Energize the cold start injection sequence and observe if fluid sprays in the jars.

☐ 6. If one or both injectors do not energize, refer to the OEM troubleshooting guide.

☐ 7. Reinstall the nozzles in the intake manifold.

☐ 8. Turn in job ticket when finished.

☐ 9. Clean work area and return tools and materials to proper storage.

Evaluator's Comments: ______________________________

____

______________________________ ____________

832

Job Sheet 7

PARTS LIST

QTY.	PARTS/MATERIALS	PRICE
TOTAL PARTS/MATERIALS		

SPECIFICATIONS CHECKED

School/Work Name ____________________
Address ____________________
Phone # ____________________

Date In ____________
Date Out ____________

JOB TICKET

Customer Name ____________________
Customer Address ____________________
Customer Phone # ____________________

Vehicle/Equip.	Make & Model	License #/Motor #/Serial #	Speedometer

Condition reported by customer/service requested: ____________________

Services/repairs made: ____________________

LABOR

Customer Authorization

I, the undersigned, have reviewed the required service and parts estimates and authorize this maintenance to be performed with the understanding that I will be notified prior to the performance of any work that significantly exceeds those estimates in time or cost.

____________________ Date ____________

Technician ____________
Supervisor ____________

Unit Contents

Student Components

Student Page

Objective Sheet 9B–3
Information Sheet 9B–5
Job Sheets
1—Remove, Inspect, Install and Adjust a Jacobs Engine Brake 9B–13
2—Check Operation of a BrakeSaver® 9B–17
3—Check Operation of an Exhaust Brake 9B–21
4—Remove, Clean, and Reinstall an Exhaust Brake 9B–25
5—Check Operation of a Driveline Retarder 9B–29

Objective Sheet

Unit Objective

After completing this unit, the student will be able to identify and describe basic engine brake and retarder systems. The student will be able to inspect, service, and repair engine brake and retarder system components and controls. The student should demonstrate these competencies by completing the job sheets and by scoring a minimum of 85 percent on the written test

Specific Objectives

After completing this unit, the student should be able to:

1. Match terms related to engine brakes and retarders with their definitions.
2. Match common types of engine brakes and retarders with their descriptions.
3. Select from a list the advantages of engine brake and retarder systems.
4. Label typical engine compression brake components.
5. Match typical engine compression brake components with their functions.
6. Complete statements concerning engine operation with the engine compression brake energized.
7. Identify exhaust brake components.
8. Match exhaust brake components with their functions.
9. Complete statements concerning engine operation with the exhaust brake energized.
10. Label hydraulic engine retarder components.
11. Match hydraulic engine retarder components with their functions.
12. Arrange in order the steps describing the engine operation with the hydraulic engine retarder energized.
13. Identify electric driveline retarder components.
14. Match electric driveline retarder components with their functions.
15. Complete statements concerning engine operation with an electric driveline retarder energized.
16. Remove, inspect, install, and adjust a Jacobs engine brake.
    (Job Sheet 1)

Objective Sheet

17. Check operation of a BrakeSaver®. (Job Sheet 2)
18. Check operation of an exhaust brake. (Job Sheet 3)
19. Remove, clean, and install an exhaust brake. (Job Sheet 4)
20. Check operation of a driveline retarder. (Job Sheet 5)

837

Information Sheet

Objective 1

Terms and definitions

a. **Air suppressor**—Device that stops air pulsations

b. **Clutch switch**—Switch that disengages compression brake when clutch is depressed

c. **Eddy current**—Circular current produced along coil windings; generates both heat and resistance to movement

d. **Electronic control module (ECM)**—Computerized device that monitors other electronic parts by receiving and sending electronic signals

e. **Engine brake**—Device that causes the vehicle to slow down by releasing the compressed air normally needed for ignition

f. **Master piston**—Piston that supplies high pressure oil to slave piston

g. **Pump switch**—Switch that disengages when clutch is depressed upon acceleration

h. **Retarder**—Any device that slows the vehicle

i. **Rheostat**—Manually operated switch that varies current flow

j. **Slave piston**—Piston that is directly responsive to master piston; operates exhaust valves

Objective 2

Common types of engine brakes and retarders

a. **Engine compression brake (Jake Brake®)**—Alters exhaust valve operation to convert the engine into an energy-absorbing vacuum pump; places tremendous drag on the piston, slowing the vehicle

b. **Exhaust brake**—Stops exhaust outflow, turning the engine into an energy-absorbing air compressor; produces drag on the pistons, slowing the vehicle

c. **Hydraulic engine retarder (BrakeSaver®)**—Uses pressurized engine oil to produce drag inside a torque converter attached to the crankshaft

d. **Driveline retarder**—Uses electromagnetic or hydraulic devices to create drag on the driveline, slowing the driving wheels

Objective 3

Advantages of engine brake and retarder systems

a. Faster, steadier, more efficient braking performance

b. Reduced wear on engine, tires, and foundation brakes

c. Reduced vehicle downtime

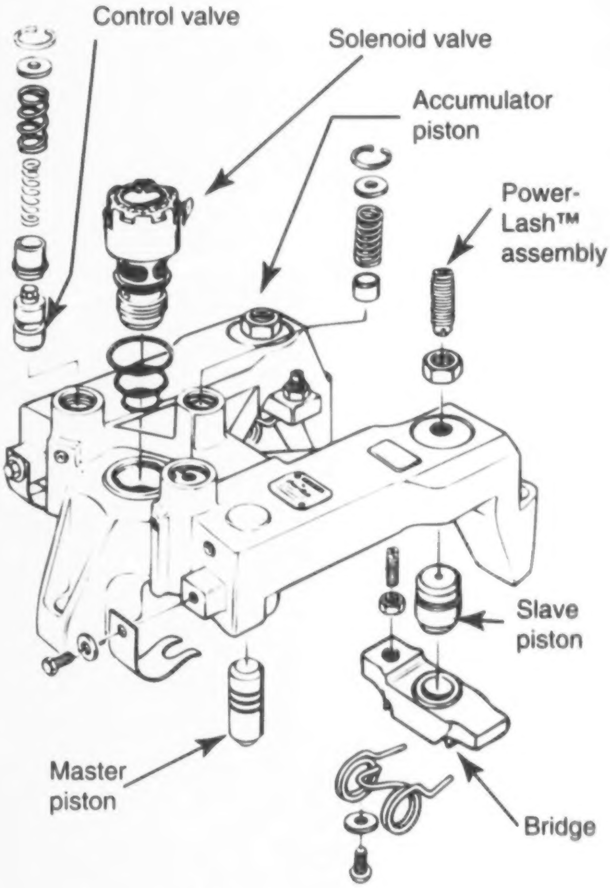
d. Improved vehicle productivity

e. Increased operator confidence

Objective 4

Engine compression brake components

Figure 1


Control valve
Solenoid valve
Accumulator piston
Power-Lash™ assembly
Slave piston
Bridge
Master piston

Courtesy of Jacobs Vehicle Systems

839

Objective 5

Functions of engine compression brake components

a. **Electric control valve**—Completes an electrical circuit, sending power to the engine brake solenoids; can be triggered by foot- or hand-operated switches or by the electronic control module ECM

b. **Solenoid valve**—Receiving power from the completed electrical circuit, it opens, allowing engine oil to flow to both the slave piston and the master piston. Engine oil pressure pushes the master piston down until it contacts the injector rocker arm adjusting screw.

c. **Master piston**—Sends high pressure oil to the slave piston when the rocker arm adjusting screw moves upward

d. **Slave piston**—Forces the exhaust rocker arm down, opening the exhaust valve(s) and releasing compression

Objective 6

Engine operation with the engine compression brake energized

a. **Intake stroke**—Intake valve(s) opens and air enters the cylinder.

b. **Compression stroke**—Air is compressed by the upward-moving piston; near TDC, the engine brake opens the exhaust valve(s), venting high pressure air from the cylinder through the exhaust system.

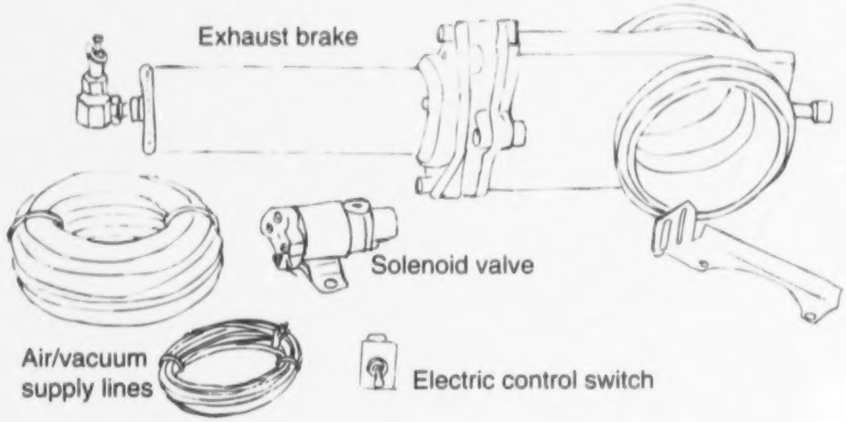
c. **Power stroke**—As the piston moves down, a strong vacuum is created; this vacuum and the loss of combustion energy provide a strong drag to the engine, flywheel, and driving wheels.

d. **Exhaust stroke**—As the piston moves up, the exhaust valves open as normal.

Objective 7

Exhaust brake components

Figure 2



Courtesy of Blue Ox Corporation

Information Sheet

Objective 8

Functions of exhaust brake components

a. **Electric control switch**—Completes an electrical circuit, sending power to the air/vacuum solenoid valve; usually triggered by the ECM

b. **Solenoid valve**—Opens, allowing either air pressure or vacuum to the exhaust brake piston

c. **Air/vacuum supply line**—Supplies the force to operate the exhaust brake

d. **Exhaust brake**—Internal piston closes a gate inside the exhaust brake housing; exhaust flow is stopped, causing exhaust gases to back up into the exhaust manifold and cylinders, creating drag each time the piston comes up

Objective 9

Engine operation with the exhaust brake energized (throttle-off operation)

a. **Intake stroke**—Intake valve(s) opens and air enters the cylinder. Complete cylinder filling is not possible because of the remaining exhaust gases.

b. **Compression stroke**—Piston moves up, compressing the air, creating engine drag.

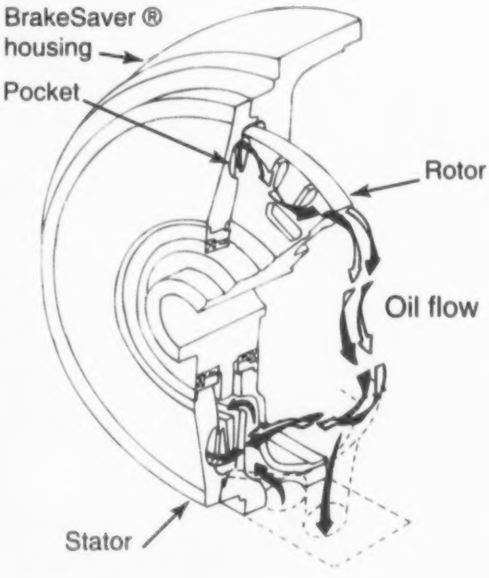
c. **Power stroke**—No fuel is injected during closed-throttle coasting, so no energy is produced, creating further drag.

d. **Exhaust stroke**—Air is unable to exit the cylinder. The rising piston meets increasing resistance.

Objective 10

Hydraulic engine retarder components (BrakeSaver®)

Figure 3



© Caterpillar Inc. Used with permission

Objective 11

Functions of hydraulic engine retarder components

a. **Control valve**—Varies the amount of oil flow to the housing; the greater the flow, the greater the braking force

b. **Housing**—Mounts to the back of the engine block and contains the oil passages; along its inside edge are pockets to provide resistance to oil flow

c. **Stator**—Bolted to the housing, it forms the back half of a hollow "doughnut;" like the housing, it has pockets along its inside edge

d. **Rotor**—Fastened to the crankshaft, it turns in the hollow space between the housing and stator

Objective 12

Engine operation with the hydraulic engine retarder energized

a. The control valve allows oil to flow into the housing.

b. Pressurized engine oil enters the housing at the bottom, begins surrounding the rotor, and fills the space between the stator and the housing.

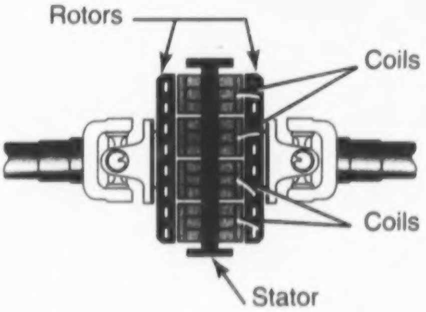
c. The vanes on the rotor constantly churn the oil, forcing it against the pockets in the stator and the housing.

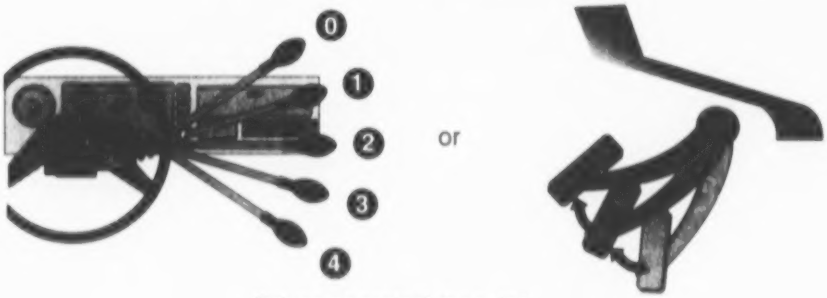
d. The resistance of the oil between the vanes and pockets provides drag to the driveline and drive wheels.

Objective 13

Electric driveline retarder components

Figure 4





Driver-operated rheostat

Courtesy of Jacobs Vehicle Systems

Objective 14

Functions of electric driveline retarder components

a. **Driver-operated rheostat**—Controls the amount of current flow to the retarder; may be hand- or foot-operated

b. **Coils**—Create strong magnetic fields when electrical current flows through them

c. **Stator**—Contains the coils and is mounted to the vehicle chassis, transmission, or axle

d. **Rotors**—Vented, circular steel discs, similar to disc brake rotors, mounted to the vehicle's driveline

Objective 15

Engine operation with an electric driveline retarder energized

a. Driver activates a multi-position switch either by hand control or through the brake pedal.

b. Current flows to the stator coils, setting up strong magnetic fields (eddy currents).

c. As the rotor passes through the magnetic fields, the eddy currents try to stop movement. This loss of motion generates great heat.

d. The vanes in the rotor force cool air over the coils, dissipating the heat.

Objective 16

Job Sheet 1—Remove, Inspect, Install, and Adjust a Jacobs Engine Brake

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Correct procedures identified for assigned vehicle	______
• Procedures completed correctly	______
• Proper tools used correctly	______
• Safety precautions observed	______
• Installed equipment functions correctly	______
• Serviced equipment meets specifications	______
• Clean-up and follow-up actions adequate	______

Basic Skills

Reading Writing Critical Thinking Employability

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, Equipment, and Materials

- Technician's common hand tools
- Appropriate service manual
- Job ticket or work order—one is included or use appropriate one provided at your facility
- Safety equipment
- Appropriate Jake Brake® OEM manual
- Feeler gauges
- Torque wrench
- Engine to be worked on
- Others—as recommended by instructor and equipment service manual

Guidelines

- Before adjusting the slave piston on a cylinder; make sure the exhaust valves are closed.

- **Never** activate a Jake Brake® unless the fuel control is in the low idle position.

- Contain loose hair and clothing to prevent it from being caught in the engine during running adjustments.

Procedure

☐ 1. Locate and follow the appropriate procedure in the service manual.

☐ 2. Complete the accompanying job ticket with all pertinent information.

☐ 3. Set parking brake, remove ignition key, and chock wheels.

☐ 4. Remove engine rocker covers.

☐ 5. Disconnect the solenoid wiring harnesses at the solenoids.

☐ 6. Remove the mounting bolts that hold each Jake Brake® assembly to the cylinder head.

☐ 7. Remove the brake assemblies and the spacer bar(s), if applicable.

☐ 8. To inspect the brake assembly, refer to the Jacobs OEM manual for that series engine brake.

☐ 9. Before reinstalling the brake assembly, set the intake and exhaust valve clearances, and set the injector heights.

☐ 10. Using a blow gun nozzle, blow the engine oil out of each bolt hole. This will prevent the cylinder head from cracking when the bolts are tightened down.

☐ 11. Install the brake housings, center them, and torque to specs. List the recommended torque below.

Jacobs brake housing torque ______________

☐ 12. Connect the solenoid wiring harness to the solenoids.

☐ 13. Adjust slave piston clearance (Jake Brake® Lash) as stated in the OEM manual. List the recommended clearance below.

Jacobs slave piston lash ______________

Caution: With the rocker cover removed, take care to avoid hot engine oil.

☐ 14. Start the engine, and allow it to reach operating temperature. With the engine at low idle, bleed air from the system by manually depressing and releasing the Jacobs solenoid armature. Do this several times to allow the housing to completely fill with oil.

☐ 15. Repeat this procedure with each brake assembly. Watch to see that the master piston is moving down onto the injector rocker arm, and that the slave piston is moving down to contact the exhaust valve rocker arm adjusting screws.

☐ 16. Stop the engine and install the valve cover. Be sure all wires are away from moving parts.

☐ 17. Check the fuel pump microswitch clearance. List the recommended clearance below.

Microswitch clearance ______________

☐ 18. Install any other components that were removed for this procedure.

☐ 19. Turn in job ticket when finished.

☐ 20. Clean work area and return tools and materials to proper storage.

Evaluator's Comments: ____

____

____

Job Sheet 1

PARTS LIST

QTY.	PARTS/MATERIALS	PRICE	
TOTAL PARTS/MATERIALS			

SPECIFICATIONS CHECKED

School/Work Name ______________________

Address ______________________

Phone # ______________________

Date In ____________

Date Out ____________

JOB TICKET

Customer Name ______________________

Customer Address ______________________

Customer Phone # ______________________

Vehicle/Equip.	Make & Model	License #/Motor #/Serial #	Speedometer

Condition reported by customer/service requested: ______________________

____

Services/repairs made: ______________________

	LABOR	

Customer Authorization

I, the undersigned, have reviewed the required service and parts estimates and authorize this maintenance to be performed with the understanding that I will be notified prior to the performance of any work that significantly exceeds those estimates in time or cost.

______________________ Date ____________

Technician ____________

Supervisor ____________

Objective 17

Job Sheet 2—Check Operation of a BrakeSaver®

Name ____________________ Attempt Number ________

Date ____________________ Overall Rating ________

Evaluation Criteria	Rating
• Correct procedures identified for assigned vehicle	______
• Procedures completed correctly	______
• Proper tools used correctly	______
• Safety precautions observed	______
• Installed equipment functions correctly	______
• Serviced equipment meets specifications	______
• Clean-up and follow-up actions adequate	______

Basic Skills

Reading Writing Critical Thinking Employability

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, Equipment, and Materials

- Technician's common hand tools
- Appropriate service manual
- Job ticket or work order—one is included or use appropriate one provided at your facility
- Safety equipment
- Appropriate BrakeSaver® OEM manual
- Engine to be worked on
- Others—as recommended by instructor and equipment service manual

Guidelines

- Ensure that engine is tuned and producing rated horsepower.

- Do not run the engine at high idle with the BrakeSaver® on for more than 15 seconds at a time. After each high idle test, allow the engine to run at low idle for at least five minutes with the BrakeSaver® off. This will prevent overheating and damage.

Procedure

☐ 1. Locate and follow the appropriate procedure in the service manual.

☐ 2. Complete the accompanying job ticket with all pertinent information.

☐ 3. Set parking brake and chock wheels.

☐ 4. Turn on the ignition, but do not start the engine. Energize the BrakeSaver®. You will hear a "clunk" as the solenoid valve opens.

☐ 5. Start engine and bring it to operating temperature.

☐ 6. Place transmission in neutral.

☐ 7. Operate the engine at high idle (foot pedal to the floor). Record engine rpm.

☐ 8. Switch the BrakeSaver® "ON." Record engine rpm.

☐ 9. The rpm drop should be between 125 rpm and 175 rpm.

☐ 10. If the rpm drop is less than 125 rpm, the BrakeSaver® unit is defective and requires service or repair.

☐ 11. If the rpm drop is more than 175 rpm, air pressure to the BrakeSaver® control valve is excessive (50 psi max).

☐ 12. Turn in job ticket when finished.

☐ 13. Clean work area and return tools and materials to proper storage.

Evaluator's Comments: ______________________________

____

____

Job Sheet 2

PARTS LIST

QTY.	PARTS/MATERIALS	PRICE	
TOTAL PARTS/MATERIALS			

SPECIFICATIONS CHECKED

School/Work Name ____________________

Address ____________________

Phone # ____________________

Date In ____________

Date Out ____________

JOB TICKET

Customer Name ____________________

Customer Address ____________________

Customer Phone # ____________________

Vehicle/Equip.	Make & Model	License #/Motor #/Serial #	Speedometer

Condition reported by customer/service requested: ____________________

Services/repairs made: ____________________

LABOR

Customer Authorization

I, the undersigned, have reviewed the required service and parts estimates and authorize this maintenance to be performed with the understanding that I will be notified prior to the performance of any work that significantly exceeds those estimates in time or cost.

____________________ Date ____________

Technician ____________

Supervisor ____________

Objective 18

Job Sheet 3—Check Operation of an Exhaust Brake

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Correct procedures identified for assigned vehicle	______
• Procedures completed correctly	______
• Proper tools used correctly	______
• Safety precautions observed	______
• Installed equipment functions correctly	______
• Serviced equipment meets specifications	______
• Clean-up and follow-up actions adequate	______

Basic Skills

Reading Writing Critical Thinking Employability

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, Equipment, and Materials

- Technician's common hand tools
- Appropriate service manual
- Job ticket or work order—one is included or use appropriate one provided at your facility
- Safety equipment
- Appropriate exhaust brake OEM manual
- Engine equipped with an exhaust brake to be worked on
- Others—as recommended by instructor and equipment service manual

Guidelines

- Be careful when working around hot exhaust components.

- Replace exhaust pipe clamps as needed.

Procedure

☐ 1. Locate and follow the appropriate procedure in the service manual.

☐ 2. Complete the accompanying job ticket with all pertinent information.

☐ 3. Set parking brake and chock wheels.

☐ 4. Remove exhaust pipe from exhaust brake housing.

☐ 5. Perform test sequence in OEM manual. Note your findings on the job ticket.

☐ 6. Reinstall the exhaust pipe and clamp.

☐ 7. Turn in job ticket when finished.

☐ 8. Clean work area and return tools and materials to proper storage.

Evaluator's Comments: ______________________________

____

____

PARTS LIST

QTY.	PARTS/MATERIALS	PRICE	
TOTAL PARTS/MATERIALS			

SPECIFICATIONS CHECKED

School/Work Name ____________________

Address ____________________

Phone # ____________________

Date In ____________________

Date Out ____________________

JOB TICKET

Customer Name ____________________

Customer Address ____________________

Customer Phone # ____________________

Vehicle/Equip.	Make & Model	License #/Motor #/Serial #	Speedometer

Condition reported by customer/service requested: ____________________

____

Services/repairs made: ____________________

LABOR	

Customer Authorization

I, the undersigned, have reviewed the required service and parts estimates and authorize this maintenance to be performed with the understanding that I will be notified prior to the performance of any work that significantly exceeds those estimates in time or cost.

____________________ Date ____________________

Technician ____________________

Supervisor ____________________

Job Sheet 3

Objective 19

Job Sheet 4—Remove, Clean, and Install An Exhaust Brake

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Correct procedures identified for assigned vehicle	______
• Procedures completed correctly	______
• Proper tools used correctly	______
• Safety precautions observed	______
• Installed equipment functions correctly	______
• Serviced equipment meets specifications	______
• Clean-up and follow-up actions adequate	______

Basic Skills

Reading Writing Critical Thinking Employability

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, Equipment, and Materials

- Technician's common hand tools
- Appropriate service manual
- Job ticket or work order—one is included or use appropriate one provided at your facility
- Safety equipment
- Appropriate exhaust brake OEM manual
- Engine equipped with an exhaust brake to be worked on
- Others—as recommended by instructor and equipment service manual

Guidelines

- Be careful when working around hot exhaust components.
- Replace exhaust pipe clamps as needed.

Procedure

☐ 1. Locate and follow the appropriate procedure in the service manual.

☐ 2. Complete the accompanying job ticket with all pertinent information.

☐ 3. Set parking brake and chock wheels.

☐ 4. Disconnect harness from exhaust brake control solenoid.

☐ 5. Disconnect air/vacuum line at solenoid.

☐ 6. Remove exhaust pipe clamp and exhaust pipe from the engine brake housing.

☐ 7. Remove clamp holding exhaust brake housing to exhaust manifold or turbocharger outlet.

☐ 8. Using the exhaust brake OEM manual as a guide, disassemble and inspect the brake unit.

☐ 9. Reassemble the brake unit, and reinstall on the engine.

☐ 10. Reinstall the air/vacuum line.

☐ 11. Reinstall the wiring harness.

☐ 12. Reinstall the exhaust pipe.

☐ 13. Turn in job ticket when finished.

☐ 14. Clean work area and return tools and materials to proper storage.

Evaluator's Comments: ____________________

____

____

859

Job Sheet 4

PARTS LIST

QTY.	PARTS/MATERIALS	PRICE	
TOTAL PARTS/MATERIALS			

SPECIFICATIONS CHECKED

School/Work Name ____________________

Address ____________________

Phone # ____________________

Date In __________

Date Out __________

JOB TICKET

Customer Name ____________________

Customer Address ____________________

Customer Phone # ____________________

Vehicle/Equip.	Make & Model	License #/Motor #/Serial #	Speedometer

Condition reported by customer/service requested: ____________________

____

Services/repairs made: ____________________

Services/repairs made	**LABOR**	

Customer Authorization

I, the undersigned, have reviewed the required service and parts estimates and authorize this maintenance to be performed with the understanding that I will be notified prior to the performance of any work that significantly exceeds those estimates in time or cost.

____________________ Date __________

Technician __________

Supervisor __________

Objective 20

Job Sheet 5—Check Operation of a Driveline Retarder

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	**Rating**
• Correct procedures identified for assigned vehicle	______
• Procedures completed correctly	______
• Proper tools used correctly	______
• Safety precautions observed	______
• Installed equipment functions correctly	______
• Serviced equipment meets specifications	______
• Clean-up and follow-up actions adequate	______

Basic Skills

Reading Writing Critical Thinking Employability

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, equipment, and materials

- Technician's common hand tools
- Appropriate service manual
- Job ticket or work order—one is included or use appropriate one provided at your facility
- Safety equipment
- Appropriate OEM retarder manual
- Inductive ammeter
- Feeler gauges
- Vehicle equipped with a driveline retarder to be worked on
- Others—as recommended by instructor and equipment service manual

Guidelines

- Engine speed range is 1200 rpm to 1500 rpm.
- Engine electrical system must be in good condition for this test to be accurate.

Procedure

☐ 1. Locate and follow the appropriate procedure in the service manual.

☐ 2. Complete the accompanying job ticket with all pertinent information.

☐ 3. Set parking brake and chock wheels.

☐ 4. With engine off, measure air gap between rotor and stator. It should not exceed .055°.

☐ 5. Start engine and bring it up to operating temperature. Raise engine running speed to 1200-1500 rpm. Engine speed must stay constant throughout the test.

☐ 6. Attach the inductive ammeter to the power feed wire for the retarder control box.

☐ 7. Select stage 1; hold for 45 seconds and record amperage draw.

☐ 8. Select stage 2; hold for 45 seconds and record amperage draw.

☐ 9. Select stage 3; hold for 45 seconds and record amperage draw.

☐ 10. Select stage 4; hold for 45 seconds and record amperage draw.

☐ 11. Compare your findings in steps 7-10 with OEM recommendations. Note any variance on your job ticket.

☐ 12. Turn in job ticket when finished.

☐ 13. Clean work area and return tools and materials to proper storage.

Evaluator's Comments: ______________________________

____

____

863

Job Sheet 5

PARTS LIST

QTY.	PARTS/MATERIALS	PRICE	
TOTAL PARTS/MATERIALS			

SPECIFICATIONS CHECKED

School/Work Name ______________________

Address ______________________

Phone # ______________________

Date In ____________

Date Out ____________

JOB TICKET

Customer Name ______________________

Customer Address ______________________

Customer Phone # ______________________

Vehicle/Equip.	Make & Model	License #/Motor #/Serial #	Speedometer

Condition reported by customer/service requested: ______________________

Services/repairs made: ______________________

LABOR	

Customer Authorization

I, the undersigned, have reviewed the required service and parts estimates and authorize this maintenance to be performed with the understanding that I will be notified prior to the performance of any work that significantly exceeds those estimates in time or cost.

______________________ Date ____________

Technician ____________

Supervisor ____________

Basic Fuel Systems and Components

Unit Contents

Student Components

Student Page

Objective Sheet 1C–3

Information Sheet 1C–5

Assignment Sheet

1—Trace Fuel Flow Through Basic Fuel Systems 1C–19

Job Sheets

1—Check Fuel Level, Quality, and Consumption 1C–23
2—Inspect and Service Basic Fuel Supply Components 1C–27

866

Objective Sheet

Unit Objective

After completing this unit, the student should be able to identify basic fuel systems and their components; trace fuel flow through basic fuel systems; check fuel level, quality, and consumption; and inspect and service basic fuel supply components. The student should demonstrate these competencies by completing the assignment and job sheets and by scoring a minimum of 85 percent on the written test.

Specific Objectives

After completing this unit, the student should be able to:

1. Match terms related to basic fuel systems and components with their definitions.
2. List major functions of fuel systems.
3. Identify the major parts of a fuel system.
4. Match parts of a fuel system with their functions.
5. Identify the parts of fuel tanks.
6. List types of fuel transfer pumps.
7. List types of primer pumps.
8. Identify the types of fuel injection systems.
9. Distinguish between the methods of injecting fuel.
10. Describe the types of controls on fuel systems.
11. Match types of fuel lines with their functions.
12. Distinguish between types of fuel filters.
13. Match types of governors with their descriptions.
14. Distinguish among classes of governors.
15. Complete statements concerning the operation of the mechanical governor.
16. Select from a list common maintenance problems on fuel systems.
17. List factors that affect fuel consumption.
18. Trace fuel flow through basic fuel systems. (Assignment Sheet 1)
19. Check fuel level, quality, and consumption. (Job Sheet 1)
20. Inspect and service basic fuel supply components. (Job Sheet 2)

Information Sheet

Objective 1

Terms and definitions

a. **Atomize**—Break down into small particles

b. **Cetane number**—Relative measure of the time delay between the beginning of fuel injection and the start of combustion

Note: In cold engine starting, a low cetane number will cause difficult starting and white exhaust smoke until the engine warms up. In engines with charge air cooling, a low cetane number fuel may also cause white exhaust smoke during light load operation.

c. **Flash point**—When fuel is heated to a point where it gives off a flammable vapor

d. **Governor**—Device that controls engine speed under various load conditions by changing fuel delivery

e. **Ignition**—Combustion of fuel mixture in the combustion chamber

f. **Ignition delay**—Period of time from injection to actual ignition

g. **Injection**—Method of forcing fuel into a chamber for combustion

h. **In-line**—Having the parts arranged in a straight line

i. **Misfiring injector**—Injector that fails to inject and atomize sufficient fuel to support combustion

j. **Nozzle**—Short tube with a tapered end or constriction used to speed up or direct the flow of fluid

k. **Prime**—To completely fill the system with fuel oil

l. **Purge**—To eliminate air in the fuel system by flushing with clean fuel

m. **Restriction**—Condition that reduces volume of fuel flow, but increases the pressure

n. **Specific gravity**—Weight of a liquid or solid compared with the weight of an equal volume of water at 60° F

o. **Unit fuel injector**—Component with the pump and nozzle combined which performs all the fuel injection functions

Objective 2

Major functions of fuel systems

a. Supplies the correct quantity of fuel

b. Times the fuel delivery

c. Controls the delivery rate

d. Atomizes the fuel

e. Distributes the fuel evenly throughout the combustion chamber

Objective 3

Major parts of a fuel system

a. Fuel tank(s)

b. Fuel transfer pump and primer

c. Fuel injection pump

d. Fuel lines and fittings

e. Fuel filters

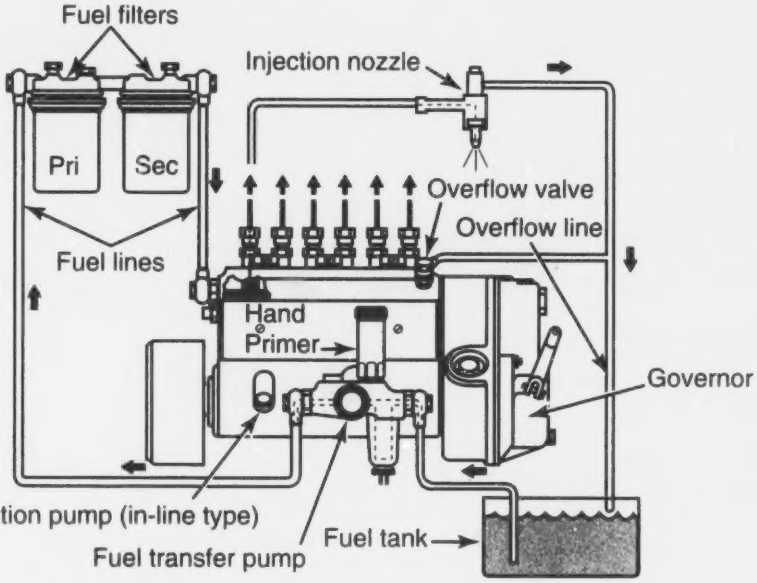
f. Optional features

   - Water separator
   - Heater
   - Check, shutoff, and/or overflow valves

g. Injection nozzles or injectors

h. Governor

Figure 1—Major parts of a fuel system


Fuel filters
Injection nozzle
Pri
Sec
Overflow valve
Overflow line
Fuel lines
Hand Primer
Governor
Fuel injection pump (in-line type)
Fuel transfer pump
Fuel tank

Courtesy of Robert Bosch Corporation

Objective 4

Functions of fuel system parts

a. **Fuel tank(s)**—Stores fuel; usually two on heavy equipment

b. **Fuel transfer pump**—Moves fuel at low pressure from fuel tank to fuel injection pump

c. **Primer or primer pump**—Bleeds air from fuel system

d. **Fuel injection pump**—Times, measures, and delivers fuel under pressure to the injection nozzles

e. **Fuel lines**—Connect the fuel system

f. **Fuel filters**—Clean the fuel by removing impurities

g. **Water separator**—Allows water to settle out of the fuel so it can be drained off

h. **Fuel heater**—Raises temperature of fuel for correct flow and firing

i. **Injection nozzle**—Atomizes and distributes fuel evenly into the combustion chamber

j. **Unit injector**—Performs functions of both the injection pump and nozzle as one unit

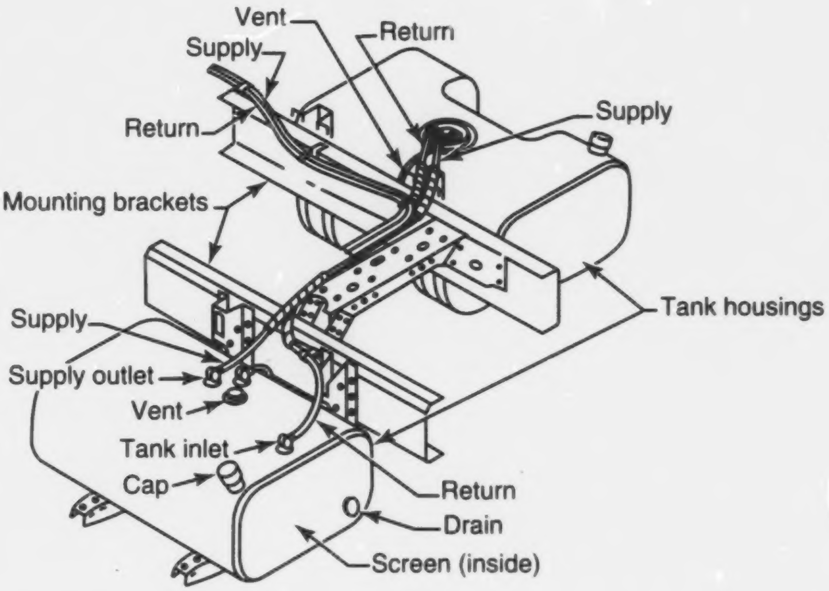
k. **Governor**—Controls the amount of fuel required to hold the engine speed reasonably constant during load fluctuations

Information Sheet

Objective 5

Parts of fuel tanks

Figure 2—Parts of fuel tanks


Vent
Supply
Return
Supply
Return
Mounting brackets
Tank housings
Supply
Supply outlet
Vent
Tank inlet
Cap
Return
Drain
Screen (inside)

Courtesy of Navistar International Transportation Corp.

Objective 6

Types of fuel transfer pumps

a. Piston type (serviceable)

b. Diaphragm type (nonserviceable)

c. Gear or rotary type

d. Electric vane type

Objective 7

Types of primer pumps

a. Mounted on primary filter

b. Mounted on piston type fuel transfer pump

c. Mounted in-line

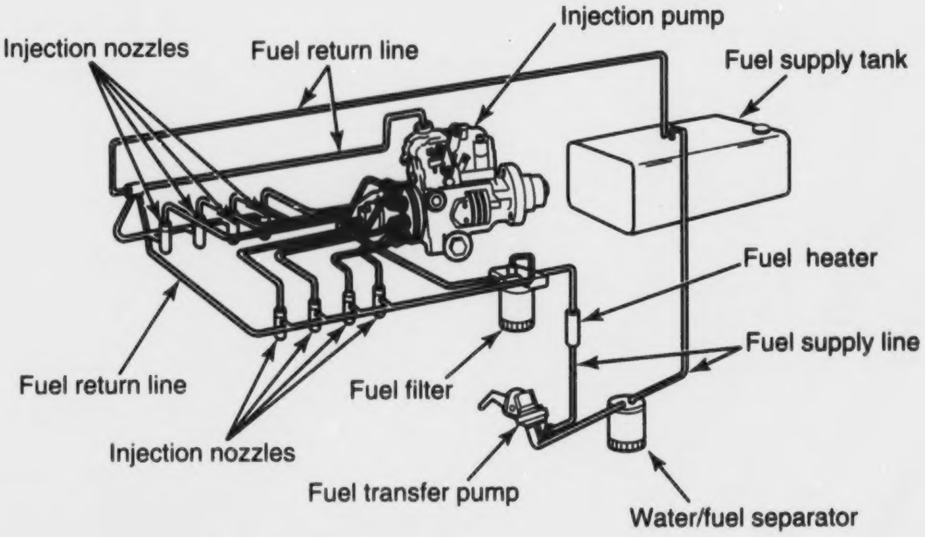
Objective 8

Types of fuel injection systems (mechanically or electronically controlled)

a. **Distributor-type (rotary) pump**

- Combines single pumping unit in a housing with a head outlet to a high pressure line to each injection nozzle
- Mounted as a separate unit on the engine

Figure 3—Distributor-type

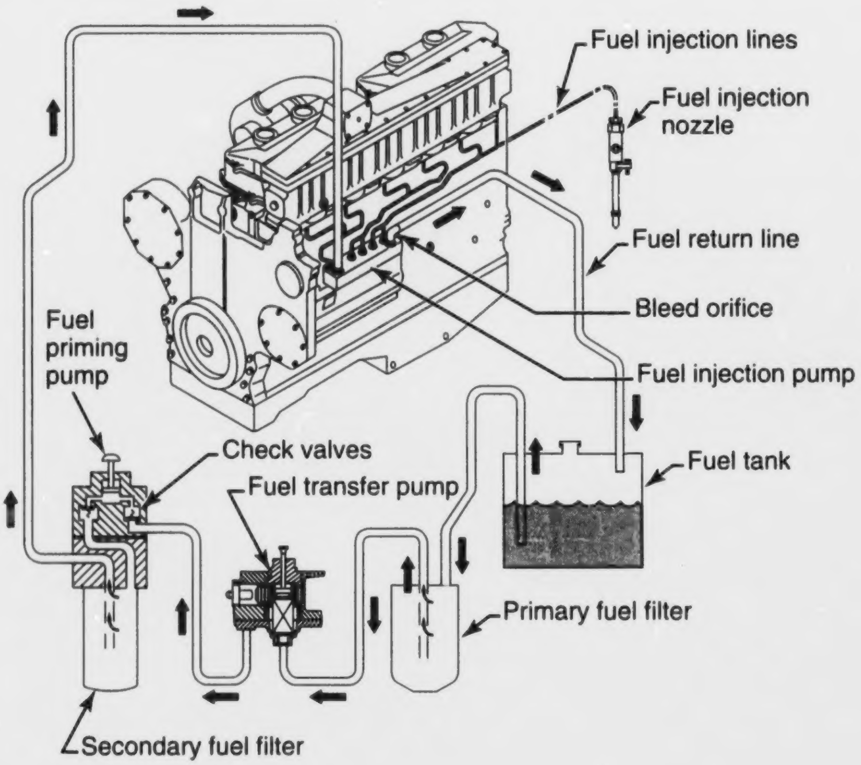

Injection pump
Injection nozzles
Fuel return line
Fuel supply tank
Fuel heater
Fuel supply line
Fuel return line
Fuel filter
Injection nozzles
Fuel transfer pump
Water/fuel separator

Reprinted with permission of Ford Motor Company

b. **In-line pump**

- Combines pumping units into a single housing that is mounted on the engine and driven by accessory drive
- Delivers fuel through high pressure lines to injection nozzles

Figure 4—In-line


Fuel injection lines
Fuel injection nozzle
Fuel return line
Bleed orifice
Fuel injection pump
Fuel priming pump
Check valves
Fuel transfer pump
Fuel tank
Primary fuel filter
Secondary fuel filter

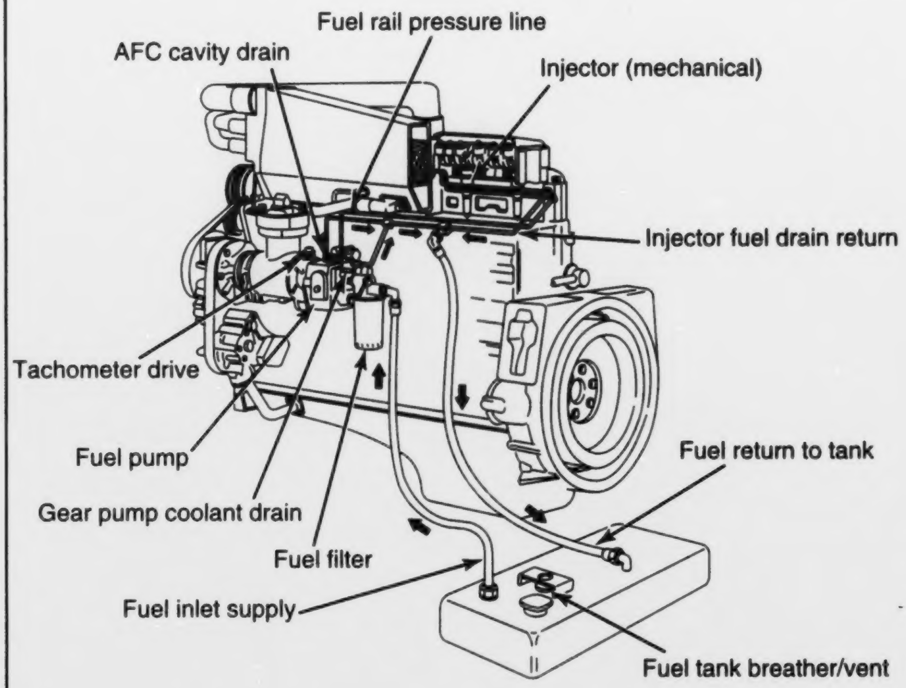
© Caterpillar Inc. Used with permission

873

c. **Pressure timed (PT) pump**

- Combines gear pump and a governor in a housing that is mounted on the engine
- Delivers fuel through common line to injectors (Cummins rail system)

Figure 5—PT

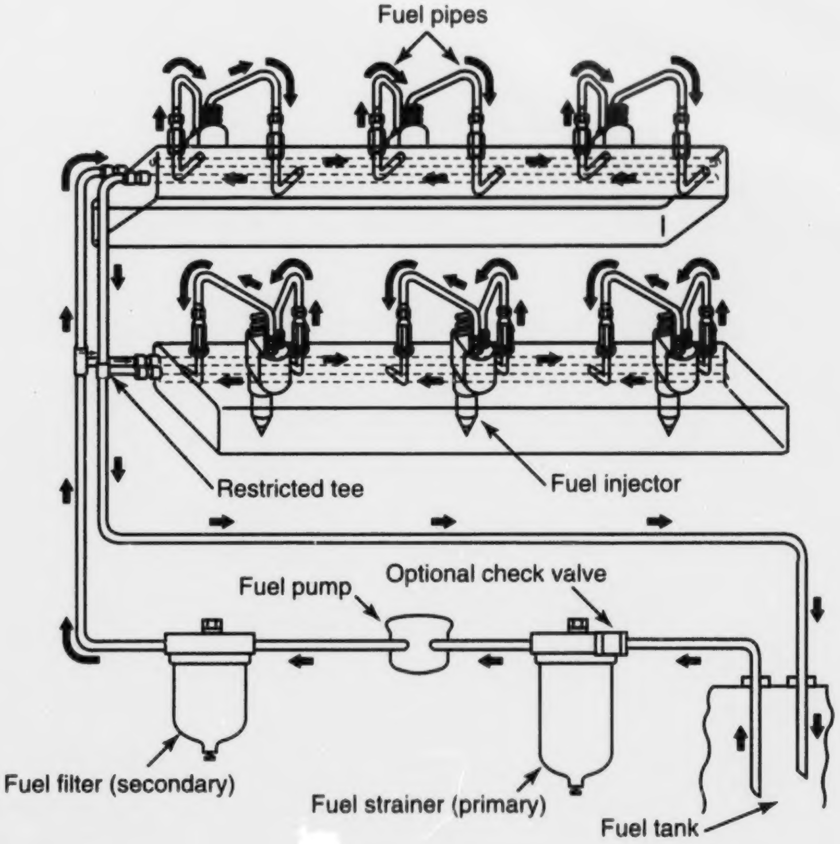

Fuel rail pressure line
AFC cavity drain
Injector (mechanical)
Injector fuel drain return
Tachometer drive
Fuel pump
Gear pump coolant drain
Fuel filter
Fuel return to tank
Fuel inlet supply
Fuel tank breather/vent

Courtesy of Cummins Engine Company, Inc.

d. **Unit Injector**

- Combines pump and injection nozzle into a single unit that is mounted on the top of each cylinder of the engine
- Delivers fuel to each cylinder

Figure 6—Unit injector


Fuel pipes
Restricted tee
Fuel injector
Fuel pump
Optional check valve
Fuel filter (secondary)
Fuel strainer (primary)
Fuel tank

Courtesy of Detroit Diesel Corporation

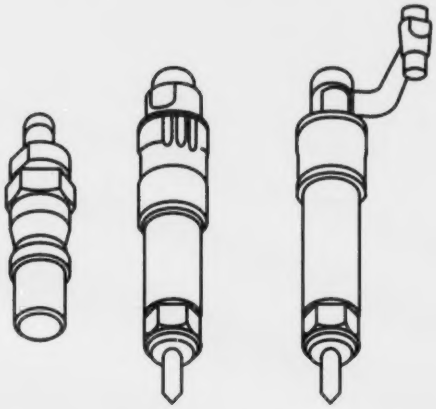
Objective 9

Methods of injecting fuel

a. **Injection nozzles**

- Used in high pressure fuel systems
- Nozzle and pump are separated and connected with a high pressure line.
- Commonly used on in-line and distributor-type injection pumps

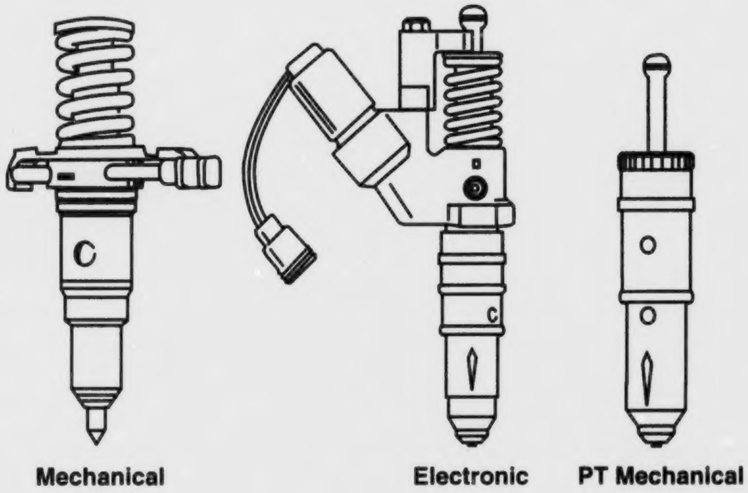
Figure 7—Injection nozzles



b. **Injectors**

- Used in low pressure fuel systems
- Operated from the engine cam through a push rod and rocker arm
- May be unit injectors or mechanical injectors
- Commonly used on PT injection pumps and unit injector systems

Figure 8—Injectors



Objective 10

Types of controls on fuel systems

a. **Mechanical**

- Uses governor flyweights to control amount of fuel delivered to injection nozzles or injectors (PT)
- Unit injectors use mechanical governor through linkage to control amount of fuel that injection delivers.

b. **Electronic**

- Uses electric solenoids and electronic control modules (ECM) to control and govern the amount of fuel delivered to the unit injector
- In-line and distributor pumps can have electronic governors mounted on the pump to control the fuel.
- PT systems may also use electronic device on top of pump to control fuel to injectors.

- Electro-hydraulic systems use engine oil raised to high pressure to the injector unit which is controlled by electronic solenoid and ECM.

  Note: Most companies are using more electronic controls, often combining them with mechanical and hydraulic systems.

Objective 11

Types of fuel lines and their functions

a. **Supply low pressure lines**—Deliver fuel from tank to fuel injection pump

b. **Schedule 80 high pressure lines**—Deliver fuel from in-line or distributor-type pump to injection nozzles

c. **Return low pressure lines**—Deliver leak-off fuel from injection nozzles to tank

Note: The lines can be made from various materials.

Objective 12

Types of fuel filters

a. **Primary filter**

- Filters out initial impurities such as dirt particles and insoluble gums in the fuel
- Is located on the suction side of the transfer pump
- Has little resistance to flow
- Sometimes has a water separator with drain at the bottom

b. **Secondary filter**

- Removes minute particles that may pass through primary filter
- Is located on the pressure side of the transfer pump
- Usually is the final filter

  Note: Fuel filters may be spin-on, clip-on, or element type. The filtering materials used for primary and secondary filters are usually of different grades and should not be interchanged.

Objective 13

Types of governors

a. **Mechanical governor**

  - Uses mechanical weights (flyweights) to move the fuel control device (metering valve or control rack) which changes the engine speed
  - Weights sense centrifugal force created by engine speed.

b. **Hydraulic governor**

  - Uses oil pressure or fuel pressure and mechanical weights to move metering valve or control rack
  - Hydraulic action is transmitted by oil admitted under pressure from the engine lubricating system to an auxiliary oil pump in the governor. The auxiliary pump then develops the oil pressure necessary to actuate the governor mechanism.

c. **Pneumatic governor**—Uses a vacuum created by air pressure differences to move the fuel control and change engine speed

d. **Electric/electronic governor**

  - Uses electronic sensors to detect engine speed changes which results in new signals to change throttle position
  - Typically used on stationary engines such as generators

Objective 14

Classes of governors

a. **Limiting speed** (road speed)

  - Restricts (limits) maximum speed of the engine and controls engine idling speed
  - Used on engines requiring minimum and maximum speed control, together with manually controlled intermediate speeds

b. **Variable speed**

  - Controls engine idle speed, restricts maximum no-load speed, and holds the engine at any constant speed (between idle and maximum) as desired by the vehicle operator
  - Used on engines subjected to varying load conditions that require an automatic fuel compensation to maintain a near constant engine speed, which may be changed manually by the operator; commonly used for construction and agriculture applications

c. **Constant speed**

  - Maintains engine speed at constant rpm
  - Used on stationary engines such as generators

Objective 15

Operation of the mechanical governor

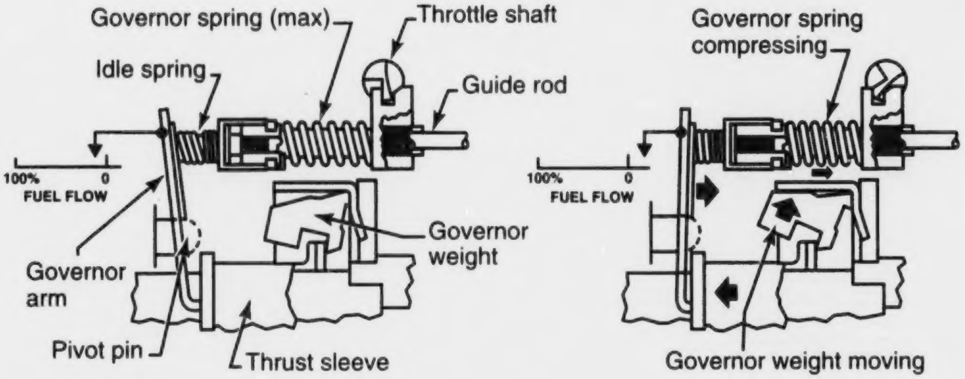
a. When more vehicle speed is desired, the operator's foot moves the foot feed which is connected through linkage (cable or rod) to the pump's throttle shaft.

b. The throttle shaft moves the governor spring and linkage to open the metering valve or move the control rack.

c. After engine speed responds (more fuel is delivered so engine speeds up), centrifugal force on the governor weights moves them outward which compresses the governor spring and cuts back fuel delivery.

d. Compressed governor spring linkage now limits maximum speed of engine.

Figure 9—Operation of a mechanical governor


Governor spring (max)
Throttle shaft
Idle spring
Guide rod
100%
0
FUEL FLOW
Governor arm
Governor weight
Pivot pin
Thrust sleeve
Governor spring compressing
100%
0
FUEL FLOW
Governor weight moving

Courtesy of Navistar International Transportation Corp.

Objective 16

Common maintenance problems on fuel systems

a. Clogged filters

b. Leaking lines

c. Tank problems—leaks, water, dirt, or clogged vent

d. Excessive fuel consumption

e. Fuel line restrictions

f. Hesitation—throttle response time incorrect

g. Low power reported by driver

h. Hard starting

Objective 17

Factors that affect fuel consumption

a. Road conditions—Gravel, bumpy, smooth, etc.

b. Weather conditions—Rain, snow, windy, extremely high or low temperatures, etc.

c. Gross vehicle weight—Vehicle + payload

d. Road speed

e. Idle time

f. Amount of time cruising vs. changing gears and speeds

g. Type of tires

h. Wind drag

i. Axle alignment

j. Fuel system leaks

k. Brake drag

l. Fuel rate, pressure, or temperature

m. Fuel system restrictions—inlet, drain, vent

n. Air inlet or exhaust restrictions

o. Fuel temperature

Objective 18

Assignment Sheet 1—Trace Fuel Flow Through Basic Fuel Systems

Name ______________________ Overall Rating __________

Date ______________________

Evaluation Criteria	Rating
• Pressurized flow is marked red	_____
• Supply/suction is marked blue	_____
• Return is marked green	_____

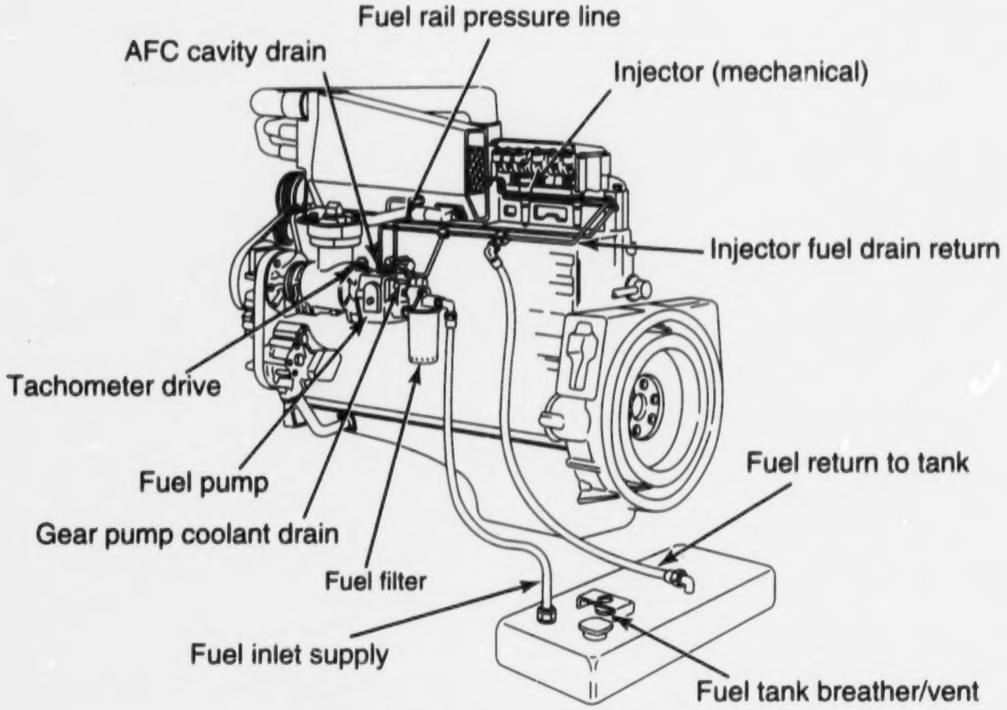
Basic Skills

Reading Mathematics Critical Thinking

Directions

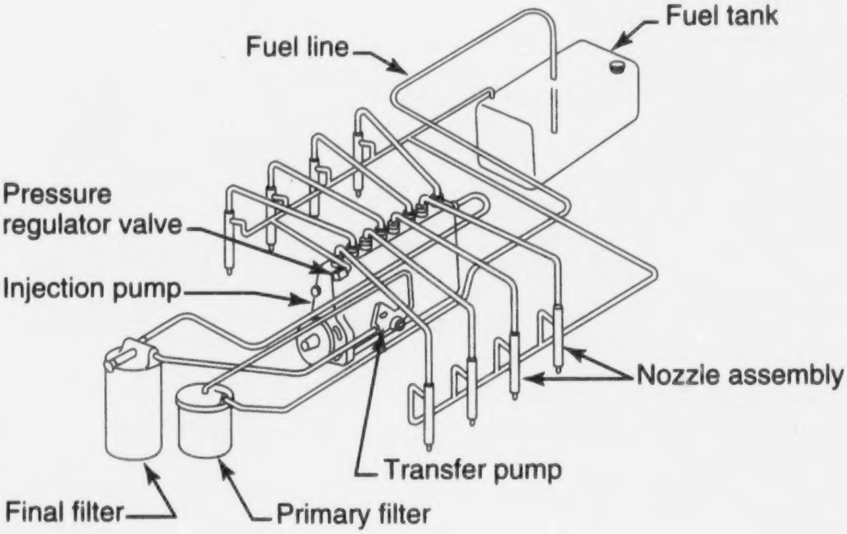
Use colored pencils or markers to trace the flow of fuel through each of the following fuel systems. Use red to identify pressurized flow, blue for supply/suction, and green for return. Add arrows to show the direction of flow.

Figure 1–PT


Fuel rail pressure line
AFC cavity drain
Injector (mechanical)
Injector fuel drain return
Tachometer drive
Fuel return to tank
Fuel pump
Gear pump coolant drain
Fuel filter
Fuel inlet supply
Fuel tank breather/vent

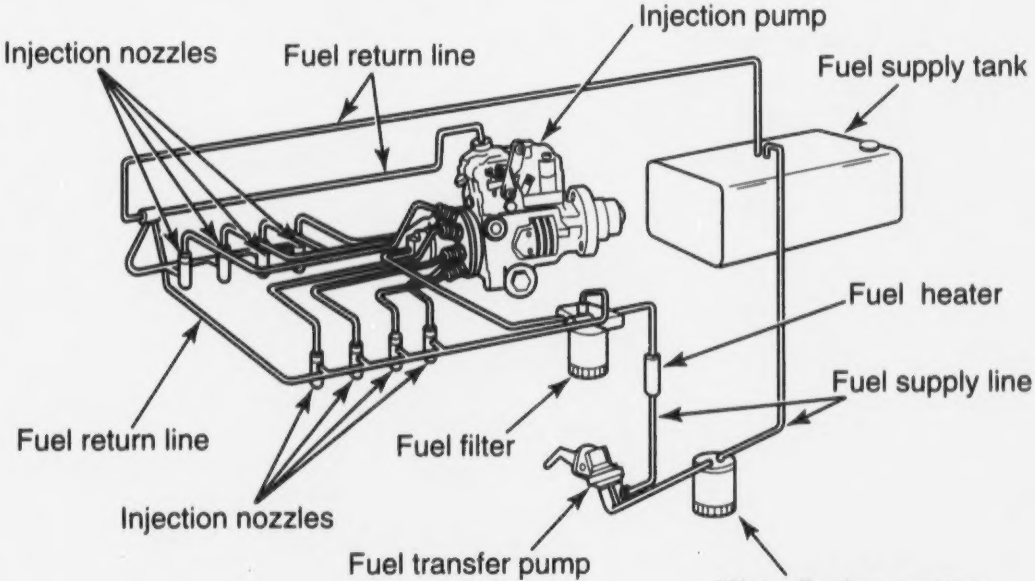
Courtesy of Cummins Engine Company

Figure 2—In-line


Fuel tank
Fuel line
Pressure regulator valve
Injection pump
Nozzle assembly
Transfer pump
Final filter
Primary filter

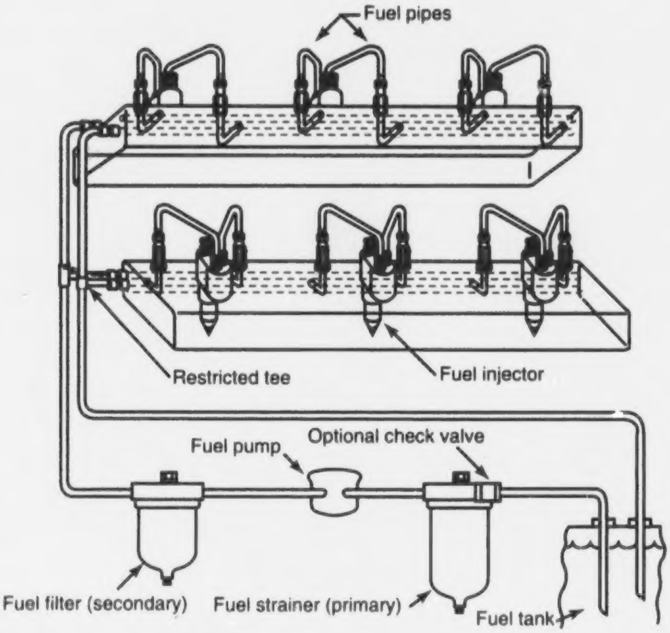
Courtesy of Navistar International Transportation Corp.

Figure 3—Distributor-type


Injection nozzles
Fuel return line
Injection pump
Fuel supply tank
Fuel heater
Fuel supply line
Fuel return line
Fuel filter
Injection nozzles
Fuel transfer pump
Water/fuel separator

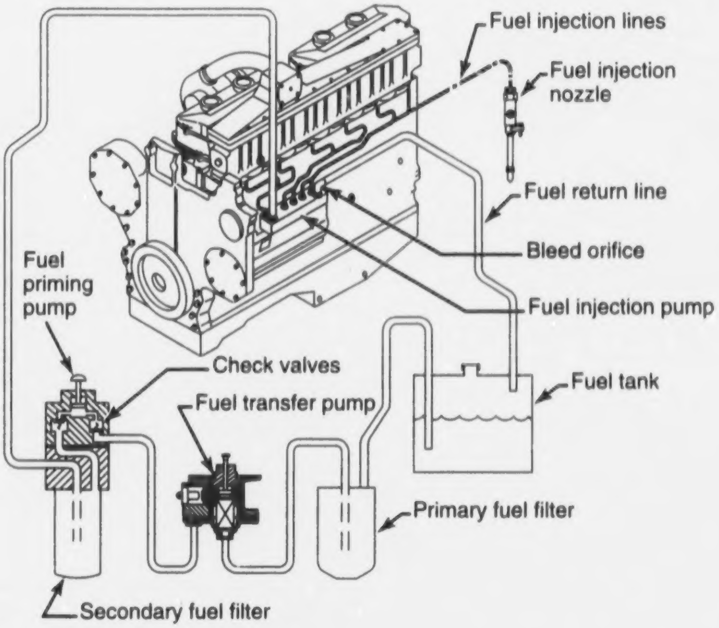
Reprinted with permission of Ford Motor Company

Figure 4—Unit injectors


Fuel pipes
Restricted tee
Fuel injector
Fuel pump
Optional check valve
Fuel filter (secondary)
Fuel strainer (primary)
Fuel tank

Courtesy of Detroit Diesel Corporation

Figure 5—In-line


Fuel injection lines
Fuel injection nozzle
Fuel return line
Bleed orifice
Fuel injection pump
Fuel priming pump
Check valves
Fuel transfer pump
Fuel tank
Primary fuel filter
Secondary fuel filter

© Caterpillar Inc. Used with permission

884

Objective 19

Job Sheet 1—Check Fuel Level, Quality, and Consumption

Name ________________________ Attempt Number ________

Date ________________________ Overall Rating ________

Evaluation Criteria	Rating
• Directions are followed	______
• Safety procedures are followed	______
• Service manual is used properly	______
• Parts are inspected accurately	______
• Specifications are checked	______
• Adjustments/replacements/repairs are made	______
• Job ticket is filled out properly	______
• Cleanup is adequate	______

Basic Skills

Reading Writing Mathematics Science Critical Thinking Employability

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, Equipment, and Materials

- Technician's common hand tools
- Appropriate service manual
- Job ticket or work order—one is included or use appropriate one provided at your facility
- Measuring stick (such as yard stick)
- Diesel fuel hydrometer
- Fuel, in tank of vehicle
- Access to vehicle's cab
- Container for fuel sample
- Fuel system to be worked on
- Others—as recommended by instructor and equipment service manual

Procedure

☐ 1. Locate and follow the appropriate procedure in the service manual.

☐ 2. Complete the accompanying job ticket with all pertinent information.

☐ 3. Check fuel level

  ☐ a. Check fuel level gauge in cab.

  ☐ b. Remove fuel tank cap.

  ☐ c. Use a measuring stick to check the actual level of fuel in the tanks (both sides).

- ☐ d. Compare results of actual test with gauge in cab. Should be equal.

  Example: 8″ of a 16″ tall tank should register 1/2 full or 1/2 empty on the gauge (depending on your attitude).

☐ 4. Check fuel quality.

- ☐ a. Draw fuel sample from the tank.
- ☐ b. Use fuel hydrometer to check specific gravity. Record on job ticket.
- ☐ c. Compare to standard readings to determine if fuel is good or bad. Record on job ticket.
- ☐ d. Check for microorganisms in fuel as indicated by black slime. Record on job ticket, report to customer, and treat as needed.

☐ 5. Check fuel consumption.

- ☐ a. Fill tank and record the number of gallons of fuel needed to reach full capacity.
- ☐ b. Determine the number of miles driven since last fill-up. Check trip odometer or driver's log.
- ☐ c. Divide the miles by the gallons to determine miles per gallon.

  Example: 500 miles ÷ 80 gallons = 6.25 mpg

  Note: Excessive fuel consumption may be caused by numerous factors.

☐ 6. When you have completed your work, have your instructor verify your work and initial this sheet.

Instructor's initials ____________________

☐ 7. Turn in job ticket when finished.

☐ 8. Clean work area and return tools and materials to proper storage.

Evaluator's Comments: ____

____

____

866

PARTS LIST

QTY.	PARTS/MATERIALS	PRICE	
TOTAL PARTS/MATERIALS			

SPECIFICATIONS CHECKED

School/Work Name ____________________

Address ____________________

Phone # ____________________

Date In __________

Date Out __________

JOB TICKET

Customer Name ____________________

Customer Address ____________________

Customer Phone # ____________________

Vehicle/Equip.	Make & Model	License #/Motor #/Serial #	Speedometer

Condition reported by customer/service requested: ____________________

Services/repairs made:	LABOR	

Customer Authorization

I, the undersigned, have reviewed the required service and parts estimates and authorize this maintenance to be performed with the understanding that I will be notified prior to the performance of any work that significantly exceeds those estimates in time or cost.

____________________ Date __________

Technician __________

Supervisor __________

Job Sheet 1

Objective 20

Job Sheet 2—Inspect and Service Basic Fuel Supply Components

Name ______________________________ Attempt Number ________

Date ______________________________ Overall Rating ________

Evaluation Criteria	Rating
• Directions are followed	______
• Safety procedures are followed	______
• Service manual is used properly	______
• Parts are inspected accurately	______
• Specifications are checked	______
• Adjustments/replacements/repairs are made	______
• Job ticket is filled out properly	______
• Cleanup is adequate	______

Basic Skills

Reading Writing Critical Thinking Employability

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, Equipment, and Materials

- Technician's common hand tools
- Appropriate service manual
- Job ticket or work order—one is included or use appropriate one provided at your facility
- New fuel filters and water separators
- Clean fuel (to add to new filters)
- Filter wrench
- Drain pan
- Digital volt-ohmmeter (DVOM)
- Clean shop towels
- Replacement fuel lines and mounting hardware, if needed
- Fuel system to be worked on
- Others—as recommended by instructor and equipment service manual

Procedure

☐ 1. Locate and follow the appropriate procedure in the service manual.

☐ 2. Complete the accompanying job ticket with all pertinent information.

☐ 3. Check mileage on fuel filters and water separators and replace as needed. Fill new filters with clean fuel to remove air as specified by manufacturer.

☐ 4. If any water is found in the old filters, drain water from fuel filter and water separator. You may also need to drain the fuel tank if water is found.

☐ 5. Prime and bleed air from fuel system. Refer to service manual for exact procedure.

☐ 6. Check fuel lines for wear, breaks, leaks, and other signs of damage. Replace as needed. If suction air leak is suspected, refer to manufacturer's troubleshooting manual.

☐ 7. Check vents on fuel tanks for signs of clogging, dirt, etc. Clean as needed.

☐ 8. Check mounting brackets and hardware for looseness and missing bolts. Service as needed.

☐ 9. Check fuel heaters (water type or electric) for correct operation. Refer to service manual. Check shut-off on heater for correct seasonal use.

☐ 10. When you have completed your work, have your instructor verify your work and initial this sheet.

Instructor's initials ____________________

☐ 11. Turn in job ticket when finished.

☐ 12. Clean work area and return tools and materials to proper storage.

Evaluator's Comments: ____

____

____

Job Sheet 2

PARTS LIST

QTY.	PARTS/MATERIALS	PRICE	
TOTAL PARTS/MATERIALS			

SPECIFICATIONS CHECKED

School/Work Name ______________________

Address ______________________

Phone # ______________________

Date In ____________

Date Out ____________

JOB TICKET

Customer Name ______________________

Customer Address ______________________

Customer Phone # ______________________

Vehicle/Equip.	Make & Model	License #/Motor #/Serial #	Speedometer

Condition reported by customer/service requested: ______________________

Services/repairs made: ______________________

LABOR	

Customer Authorization

I, the undersigned, have reviewed the required service and parts estimates and authorize this maintenance to be performed with the understanding that I will be notified prior to the performance of any work that significantly exceeds those estimates in time or cost.

______________________ Date ____________

Technician ____________

Supervisor ____________

Unit 2-C

Mechanical Fuel Injection Diagnosis and Repair

Unit Contents

Student Components

Student Page

Objective Sheet 2C-3

Information Sheet 2C-5

Job Sheets

1—Isolate, Remove, Test, Rebuild or Replace,
and Reinstall Injection Nozzles 2C-21
2—Isolate, Remove, Test, and Reinstall or Replace
Mechanical Unit Injectors 2C-25
3—Inspect, Test, Adjust, and Time a Distributor-Type
(Rotary) Injection Pump; Determine Needed Repairs 2C-29
4—Inspect, Test, Adjust, and Time an In-line Injection Pump;
Determine Needed Repairs 2C-33
5—Inspect, Test, and Adjust a PT Injection Pump
and Time the Injectors; Determine Needed Repairs 2C-37

Objective Sheet

Unit Objective

After completing this unit, the student should be able to identify the basic parts and discuss the operation of injection nozzles, unit injectors, distributor-type injection pumps, in-line injection pumps, and PT injection pumps. The student should also be able to isolate, remove, test, and reinstall or replace injection nozzles and unit injectors, as well as be able to inspect, test, remove, reinstall, adjust, and time basic injection pumps. The student should demonstrate these competencies by completing the job sheets and by scoring a minimum of 85 percent on the written test.

Specific Objectives

After completing this unit, the student should be able to:

1. Match terms related to mechanical fuel injection with their definitions.
2. Label the parts of an injection nozzle.
3. Distinguish between types of nozzle valves.
4. Complete statements concerning the operation of an injection nozzle.
5. Identify parts of mechanical unit injectors.
6. Arrange in order the steps describing the fuel flow through the unit injector.
7. List optional features on fuel injection pumps.
8. Identify the main parts of a distributor-type injection pump.
9. Match the main parts of a distributor-type injection pump with their functions.
10. Complete statements concerning the operation of distributor-type injection pumps.
11. Arrange in order the steps describing the fuel flow through distributor-type injection pumps.
12. Identify the main parts of an in-line injection pump.
13. Match the main parts of an in-line injection pump with their functions.
14. Complete statements concerning the operation of an in-line injection pump.
15. Label the parts and design features of a pumping element.
16. Complete statements concerning the operation of the control rack and sleeve.

17. Identify the plunger and rack positions.

18. Select from a list the types of PT injection pumps.

19. Identify the main parts of a PT injection pump.

20. Match the main parts of a PT injection pump with their functions.

21. Complete statements concerning the operation of a PT injection pump.

22. Identify types of PT injectors.

23. Match the steps in the operation of PT injectors with their descriptions.

24. Isolate, remove, test, rebuild or replace, and reinstall injection nozzles. (Job Sheet 1)

25. Isolate, remove, test, and reinstall or replace mechanical unit injectors. (Job Sheet 2)

26. Inspect, test, adjust, and time a distributor-type (rotary) injection pump; determine needed repairs. (Job Sheet 3)

27. Inspect, test, adjust, and time an in-line injection pump; determine needed repairs (Job Sheet 4)

28. Inspect, test, and adjust a PT injection pump and time the injectors; determine needed repairs. (Job Sheet 5)

Information Sheet

Objective 1

Terms and definitions

a. **Aneroid**—Smoke limiting device

b. **Annular groove**—Machined recess forming a ring on pumping plunger

c. **Circuit**—Complete path of fuel flow

d. **Delivery valve**—Type of valve that provides retraction of delivery line pressure causing nozzle valve to return to its seat, thereby preventing dribble of fuel into combustion chamber

e. **Helix**—Spiraled, machined recess on pumping plunger

f. **Gallery**—Long, narrow fuel or oil passage

g. **Governor**—A speed-sensing device that employs centrifugal force and spring tension to govern the engine speed

h. **Hydraulic**—Operated or moved by liquid in motion

i. **Maximum fuel output**—Greatest amount of fuel an injector is capable of delivering as measured by a calibrator

j. **Maximum full load speed**—Maximum speed that an engine will reach when developing full horsepower

k. **Metering**—Precision measurement of fuel delivery

l. **Orifice**—Small hole

m. **Pintle**—Valve in which the end extends into a shank or pin

n. **Registry**—Oil passage that indexes with a port in a rotating head

o. **Retraction**—Act of drawing back

p. **Servomechanism**—Automatic device for controlling large amounts of power with small amounts of power as a piston is moved by fluid under pressure

q. **Spray tip orifices**—Holes through the wall at the end of the tip which allow fuel to be sprayed into the combustion chamber

Objective 2 | **Parts of injection nozzles**

Figure 1—Typical injection nozzle

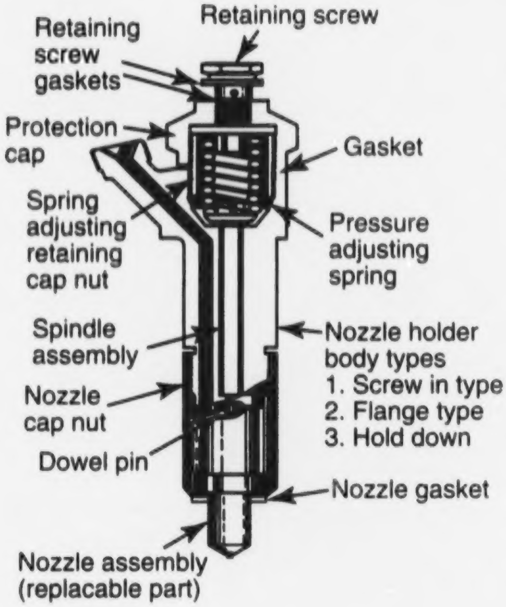
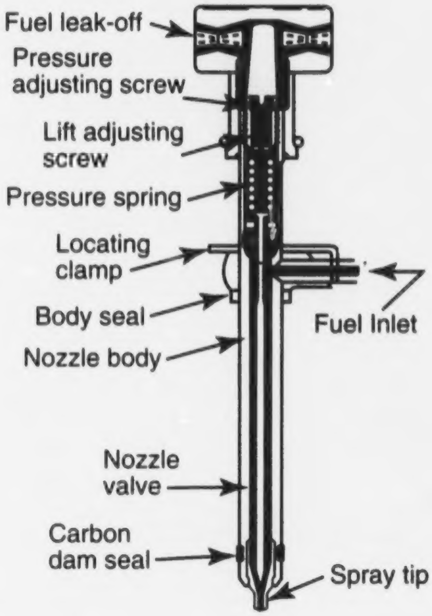

Retaining screw
Retaining screw gaskets
Protection cap
Gasket
Spring adjusting retaining cap nut
Pressure adjusting spring
Spindle assembly
Nozzle holder body types
1. Screw in type
2. Flange type
3. Hold down
Nozzle cap nut
Dowel pin
Nozzle gasket
Nozzle assembly (replacable part)

Figure 2—Pencil-type injection nozzle

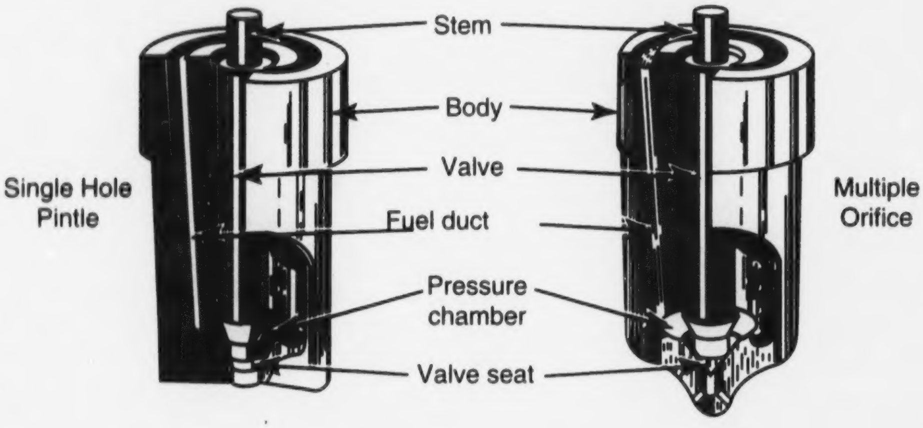

Fuel leak-off
Pressure adjusting screw
Lift adjusting screw
Pressure spring
Locating clamp
Body seal
Fuel Inlet
Nozzle body
Nozzle valve
Carbon dam seal
Spray tip

Objective 3 | **Types of nozzle valves**

a. **Single hole pintle**—Used on precombustion engines

b. **Multiple orifice**—Used on direct injection engines

Figure 3—Nozzle valves


Stem
Body
Single Hole Pintle
Valve
Multiple Orifice
Fuel duct
Pressure chamber
Valve seat

Objective 4

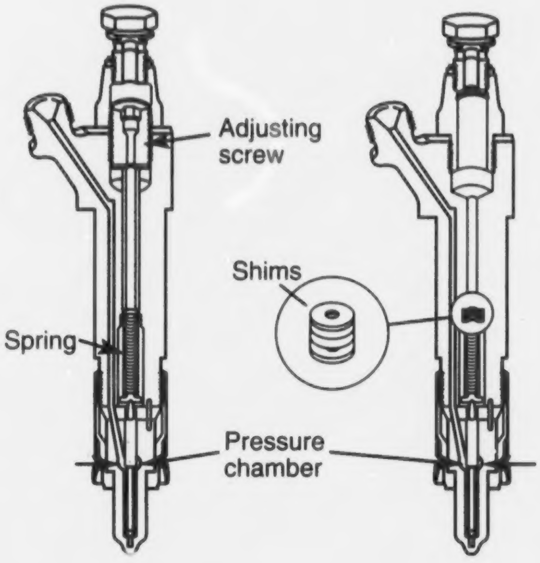
Operation of an injection nozzle

a. Fuel is delivered under pressure from the injection pump to the injection nozzle through passage to pressure chamber.

b. Spring-loaded valve is lifted allowing pressurized fuel to spray out through one or more orifices into combustion chamber.

c. Nozzle opening pressure is adjusted by a screw or shims on the valve spring.

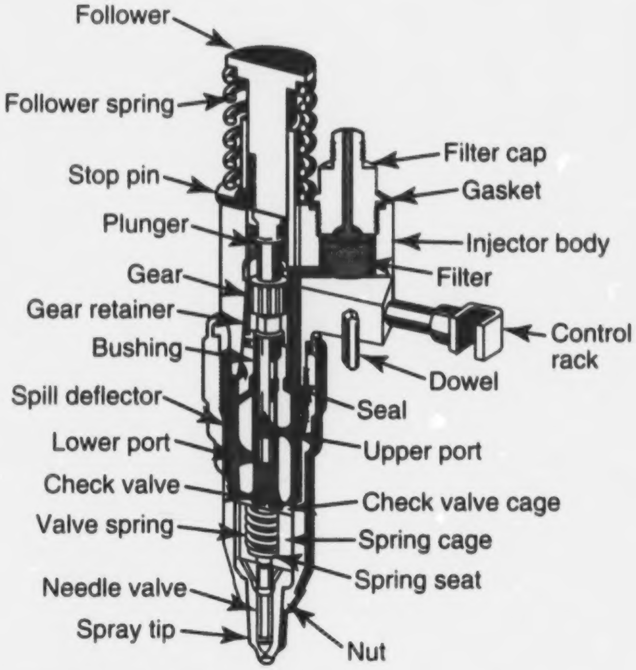
Figure 4—Nozzle adjustment



Objective 5

Parts of mechanical unit injectors

Figure 5


Follower
Follower spring
Stop pin
Plunger
Gear
Gear retainer
Bushing
Spill deflector
Lower port
Check valve
Valve spring
Needle valve
Spray tip
Filter cap
Gasket
Injector body
Filter
Control rack
Dowel
Seal
Upper port
Check valve cage
Spring cage
Spring seat
Nut

Courtesy of Detroit Diesel Corporation

Objective 6

Fuel flow through the unit injector

a. Fuel enters injector through a filter cap and filter.

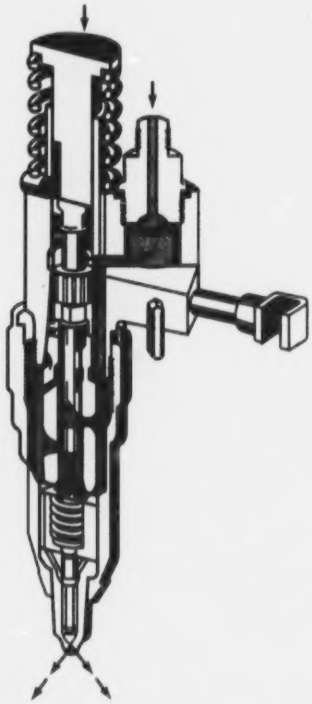
b. Fuel passes through drilled passages and ports into supply chamber.

Note: The supply chamber is that area between the plunger bushing and the spill deflector, in addition to that area under the injector plunger within the bushing.

c. Pump pressure forces fuel through small orifices in spray tip.

d. Fuel is atomized into combustion chamber.

Figure 6—Fuel flow through unit injector



Courtesy of Detroit Diesel Corporation

Objective 7

Optional features on fuel injection pumps

a. Altitude compensator

b. Aneroid control (smoke limiter)

c. Automatic load advance

d. Automatic speed advance

e. Centrifugal governor

f. Electric shut-off

g. Torque control

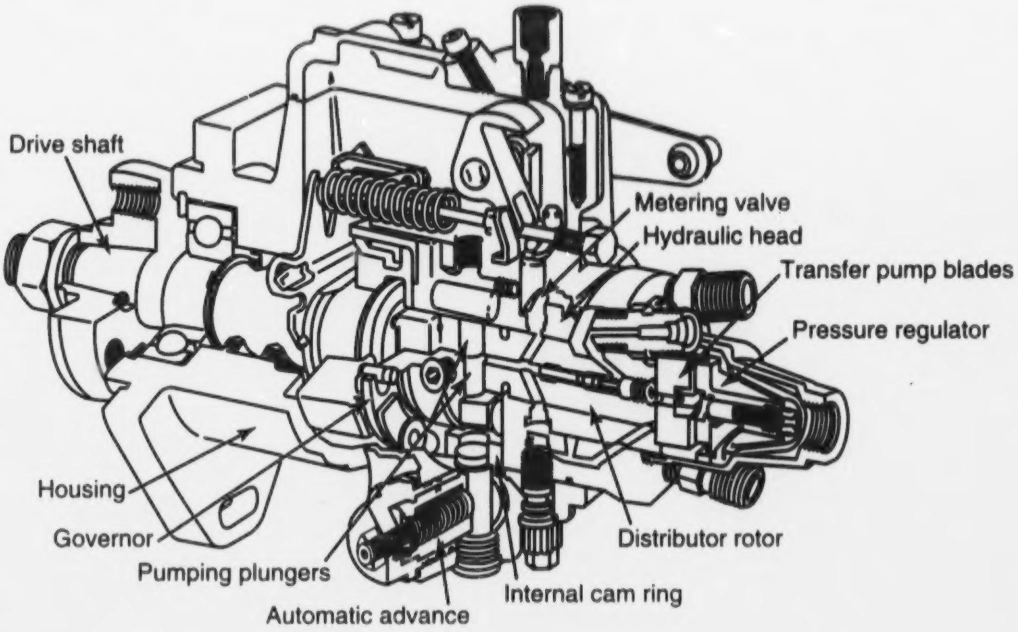
h. Viscosity compensator

Information Sheet

Objective 8

Main parts of a distributor-type injection pump

Figure 7


Drive shaft
Metering valve
Hydraulic head
Transfer pump blades
Pressure regulator
Housing
Governor
Pumping plungers
Automatic advance
Internal cam ring
Distributor rotor

Courtesy of Stanadyne, Inc.

Objective 9

Functions of main parts of a distributor-type injection pump

a. **Drive shaft**—Turns distributor rotor in the hydraulic head

b. **Metering valve**—Regulates the quantity of fuel delivered to the cylinders

c. **Hydraulic head**—Contains the metering valve and the bore in which the rotor revolves

d. **Transfer pump**—Draws fuel from supply tank through inlet strainer to injection pump

Note: Some applications may also require a lift pump.

e. **Pressure regulator**—Limits pressure of fuel to injection nozzles

f. **Distributor rotor**—Rotation of rotor causes pumping action of plungers which discharge fuel when passages index with appropriate passages in the hydraulic head

g. **Internal cam ring**—Actuates the pumping plungers

h. **Automatic advance**—Hydraulic servomechanism powered by fuel pressure from the transfer pump which advances injection timing

Note: Not all pumps are equipped with an automatic advance.

i. **Pumping plungers**—Provide pressure to transfer fuel from rotor to hydraulic head to injection nozzles

j. **Governor**—Regulates the speed by positive mechanical linkage to metering valve

k. **Housing**—Contains all component parts

Objective 10

Operation of distributor-type injection pumps

a. Drive shaft engages the distributor rotor in the hydraulic head.

Note: Drive end of rotor has two cylinder bores, each containing two plungers.

b. Plungers are actuated toward each other simultaneously by the internal cam-ring to pump fuel.

c. As rotor revolves inside hydraulic head, the discharge passage in the rotor indexes with appropriate passage in the hydraulic head to lead to the injector nozzles.

Objective 11

Fuel flow through distributor-type injection pump

a. Fuel is drawn from the supply tank through filters into the pump through the inlet filter screen by the vane type fuel transfer pump.

b. Some fuel is by-passed through the pressure regulator assembly to the suction side.

c. Fuel under transfer pump pressure flows past the rotor retainers into an annulus on the rotor.

d. Fuel then flows through a connecting passage in the head to the advance and also to the charging circuit.

e. The fuel flows around the annulus through a connecting passage to the metering valve.

f. The radial position of the metering valve, controlled by the governor, regulates the flow of fuel into the charging annulus which incorporates the charging ports.

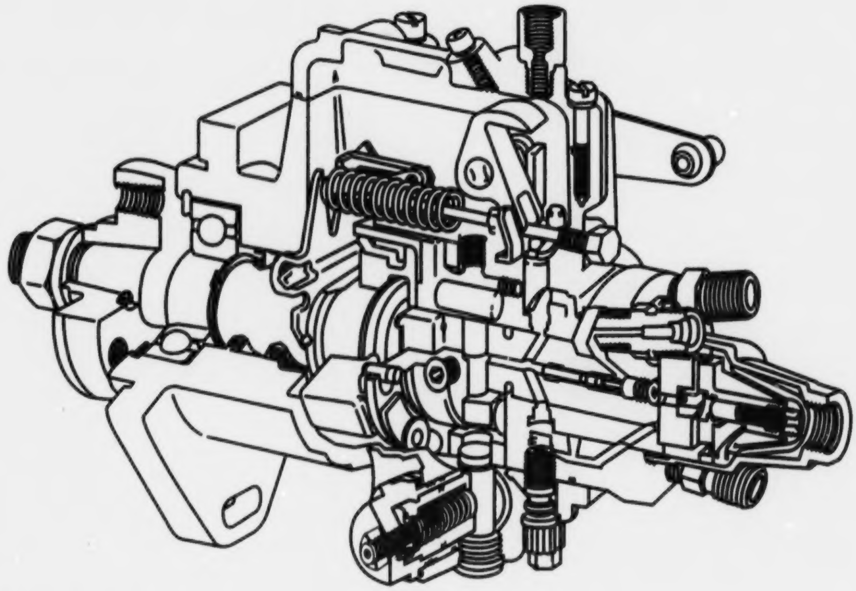
g. As the rotor revolves, the two inlet passages register with the charging ports in the hydraulic head, allowing fuel to flow into the pumping chamber.

h. With further rotation, the inlet passages move out of registry and the discharge port of the rotor registers with one of the head outlets.

i. While the discharge port is opened, the rollers contact the cam lobes forcing the plungers together.

j. Fuel trapped between the plungers is then pressurized and delivered by the nozzle to the combustion chamber.

Figure 8—Fuel flow through distributor-type injection pump

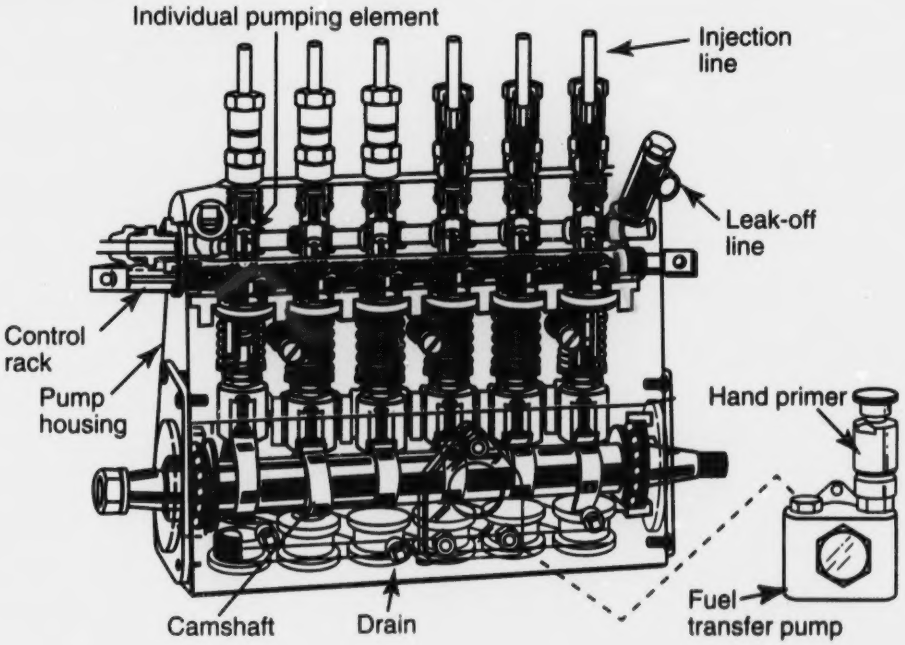


Courtesy of Stanadyne, Inc.

Objective 12

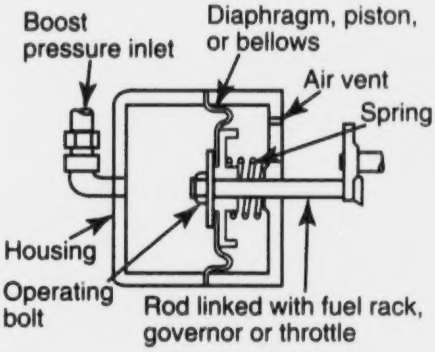
Main parts of an in-line injection pump

Figure 9


Individual pumping element
Injection line
Leak-off line
Control rack
Pump housing
Hand primer
Camshaft
Drain
Fuel transfer pump

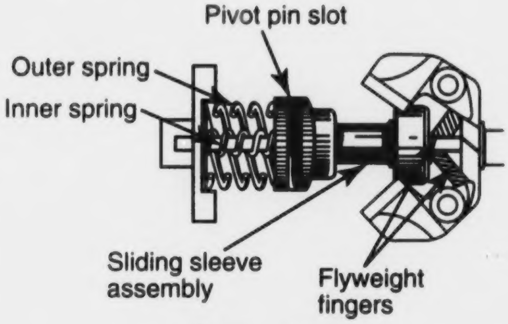
Reprinted with permission of Ambac International Corporation

Figure 10


Boost pressure inlet
Diaphragm, piston, or bellows
Air vent
Spring
Housing
Operating bolt
Rod linked with fuel rack, governor or throttle

Aneroid

Figure 11


Pivot pin slot
Outer spring
Inner spring
Sliding sleeve assembly
Flyweight fingers

Governor

Reprinted with permission of Ambac International Corporation

Objective 13

Functions of main parts of an in-line injection pump

a. **Aneroid**—Limits fuel supply to engine in order to prevent excess smoke

b. **Individual pumping element**—Opens or closes the helix on plunger to meter the quantity of fuel delivered to cylinders

c. **Injection line**—Supply line for fuel to injection nozzles

d. **Leak-off line**—Return line for excess fuel not used by injection nozzles

e. **Pump housing**—Contains all component parts

f. **Hand primer**—Pumps fuel when bleeding the system; commonly located on the fuel transfer pump

g. **Sediment bowl**—Collects contaminants in the fuel system; commonly found on the bottom of filters

h. **Fuel transfer pump**—Draws fuel from supply tank and then sends fuel at low pressure through filters to the injection pump

i. **Camshaft**—Actuates the pumping plungers

j. **Control rack**—Rotates sleeve which connects to vanes on plunger

k. **Governor**—Uses centrifugal force and spring tension to govern engine speed

Objective 14

Operation of an in-line injection pump

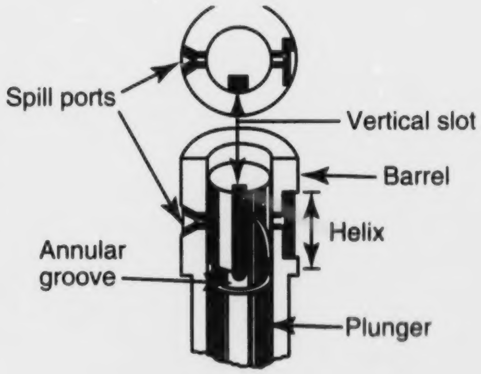
a. Plunger-type pump has engine-driven camshaft rotating at half-engine speed.

b. Roller cam followers, riding on cam lobes, operate the plungers to supply high pressure fuel through delivery valves to injection nozzles.

Objective 15

Parts and design features of a pumping element

Figure 12



Objective 16

Operation of control rack and sleeve

a. Governor moves rack to regulate speed of engine.

b. The sleeve, rotated by the control rack, is fitted over the barrel and connects to the vanes on the plunger.

c. Plunger rotation opens or closes the helix which meters the quantity of fuel for delivery to cylinder.

Figure 13—Control rack, sleeve, mechanism and delivery valve

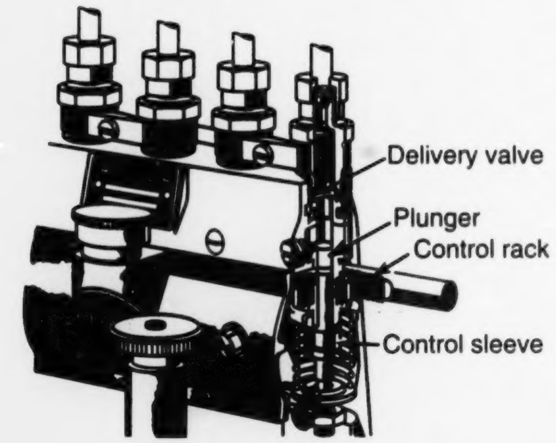
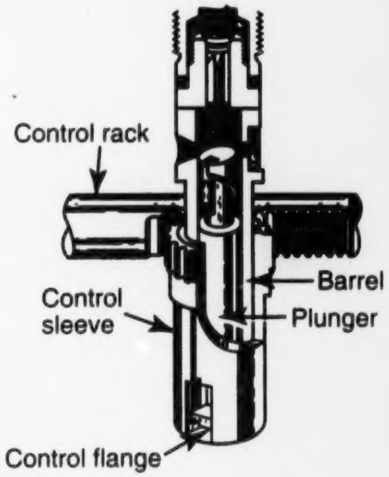

Delivery valve
Plunger
Control rack
Control sleeve

Figure 14—Plunger rotation and delivery valve


Control rack
Barrel
Control sleeve
Plunger
Control flange

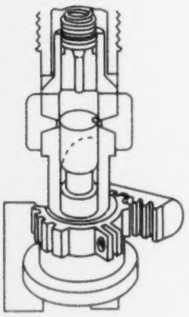
Reprinted with permission of Ambac International Corporation

Objective 17

Plunger and rack positions

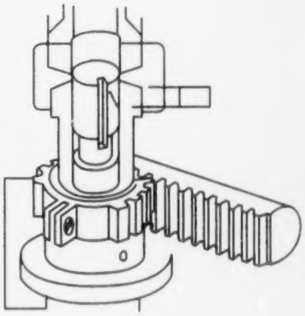
a. No fuel delivery

Figure 15



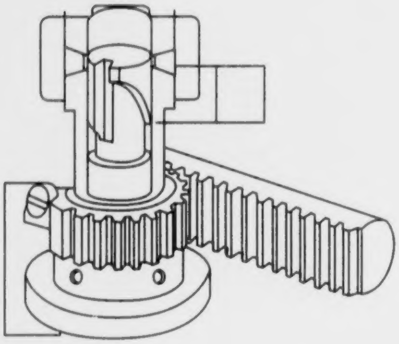
b. Partial fuel delivery

Figure 16



c. Maximum fuel delivery

Figure 17



Objective 18

Types of PT injection pumps (Cummins only)

a. PT type G—Governor controlled

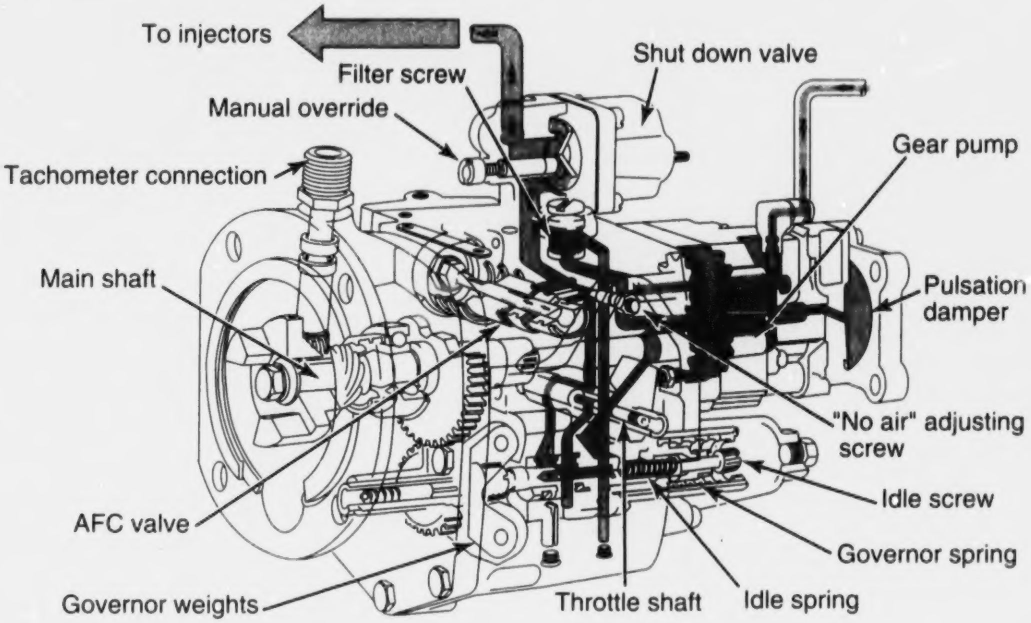
b. PTG-AFC—With air-fuel ratio control

c. PTG-AFC-VS—With air-fuel ratio control and variable speed

Objective 19

Main parts of a PT injection pump

Figure 18


To injectors
Filter screw
Shut down valve
Manual override
Tachometer connection
Gear pump
Main shaft
Pulsation damper
"No air" adjusting screw
Idle screw
AFC valve
Governor spring
Governor weights
Throttle shaft
Idle spring

Courtesy of Cummins Engine Company, Inc.

Objective 20

Functions of the main parts of a PT injection pump

a. **Gear pump**—Draws fuel from supply tank forcing it through the pump filter screen

b. **Pulsation damper**—Absorbs pulsations and smoothes fuel flow through system

c. **AFC valve**—Manifold pressure controls air-fuel ratio and fuel rate

d. **Throttle**—Provides manual control of fuel flow to injector under all conditions in operating range

e. **Governor assembly**—Controls flow of fuel from idle to maximum governor speed

f. **Shut down valve**—Stops fuel flow for shut-down of engine; may have a manual override

Objective 21

Operation of a PT injection pump

a. Gear type fuel pump delivers fuel through a restricting throttle to the governor.

b. From the governor, the fuel goes to a manifold which feeds cam-operated injectors in the cylinder head.

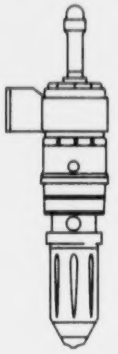
c. Injector raises pressure to produce a good spray and times the start of injection.

Objective 22

Types of PT injectors

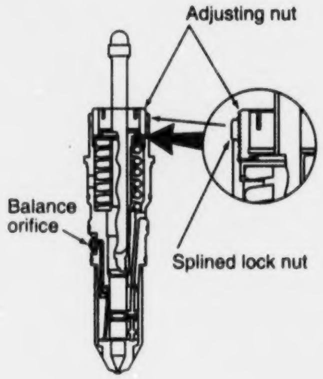
a. STC (step timing control)

Figure 19—STC injector



b. Top stop

Figure 20—Top stop injector



Courtesy of Cummins Engine Company, Inc.

Objective 23

Operation of PT injectors

a. **Metering**

- Fuel enters the injector at fuel inlet.

  Note: Pressure is determined by throttle and/or governor.

- Balance orifice controls quantity of fuel that enters the injector cup.

  Note: Pressure is determined by the fuel pump and the time interval during which the hole supplying the fuel is uncovered by the injector plunger. This is controlled by cam profile.

b. **Injection**

- Downward plunger movement cuts off fuel entry into the injector cup.
- Continued downward movement forces fuel from injector cup through the spray orifices into combustion chamber.

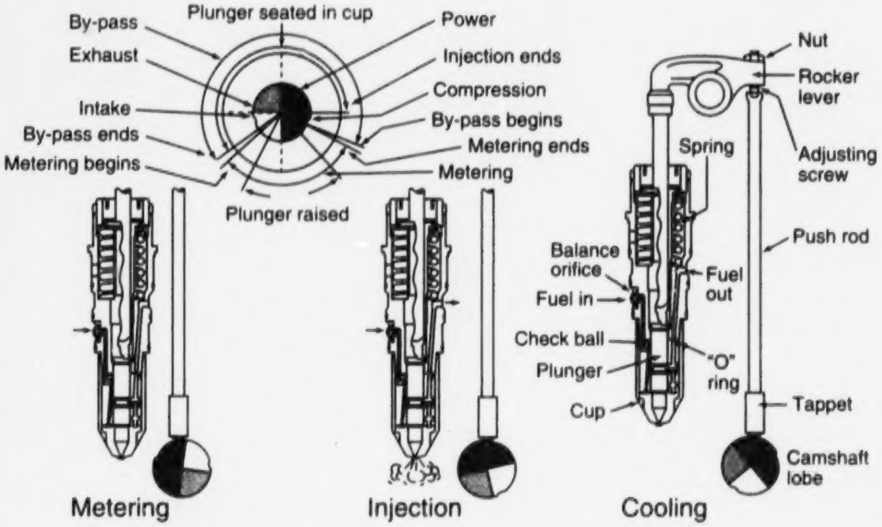
  Note: High pressures allow for almost complete burning of fuel spray.

c. **Cooling**

- While plunger is down, fuel passes through upper hole around undercut in plunger through return passages to the fuel tank.
- Plunger remains seated after injection.

Note: Fuel flows through the injector cooling it and warming tank fuel through this stage. Plunger rises back to metering operation.

Figure 21—Operation of PT injectors


By-pass
Plunger seated in cup
Power
Exhaust
Injection ends
Compression
Intake
By-pass begins
By-pass ends
Metering ends
Metering begins
Metering
Plunger raised
Nut
Rocker lever
Adjusting screw
Spring
Push rod
Balance orifice
Fuel in
Fuel out
Check ball
"O" ring
Plunger
Cup
Tappet
Camshaft lobe
Metering
Injection
Cooling

Courtesy of Cummins Engine Company, Inc.

Objective 24

Job Sheet 1—Isolate, Remove, Test, Rebuild or Replace, and Reinstall Injection Nozzles

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Directions are followed	______
• Safety procedures are followed	______
• Service manual is used properly	______
• Parts are inspected accurately	______
• Specifications are checked	______
• Faulty nozzle(s) is located	______
• Adjustments/replacements/repairs are made	______
• Replaced nozzle(s) works correctly, opening pressure ok, no leaks	______
• Job ticket is filled out properly	______
• Cleanup is adequate	______

Basic Skills

Reading Writing Science Critical Thinking Employability

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, Equipment, and Materials

- Technician's common hand tools
- Appropriate service manuals
- Job ticket or work order—one is included or use appropriate one provided at your facility
- Safety equipment
- Remote tachometer or infrared gun
- Nozzle tester
- Special service tools (or kit)
- Torque wrench
- Clean diesel fuel
- Clean shop towels
- Cleaning solvent
- Brass wire brush
- Mechanical fuel injection system to be worked on
- Others—as recommended by instructor and equipment service manual

Job Sheet 1

Guidelines

- Nozzles require careful handling and special service tools.
- When working on several nozzles, **do not** mix nozzle parts.
- Follow special safety precautions when working with nozzles. The fuel comes out of the nozzle at extremely high pressure which can penetrate clothing and skin and cause injury. Always keep the nozzle pointed away from you or enclose in a beaker when testing.

Procedure

☐ 1. Locate and follow the appropriate procedure in the service manual.

☐ 2. Complete the accompanying job ticket with all pertinent information.

☐ 3. Isolate the faulty injection nozzle or nozzles using a remote tachometer or infrared gun.

  ☐ a. Loosen nut on high pressure line to each nozzle, one at a time.

  ☐ b. Listen for a change in engine speed, and watch tachometer for an rpm drop. No change indicates a bad nozzle.

  ☐ c. If no change is noted, remove and check nozzle.

  ☐ d. Refer to manufacturer's service manual for complete instructions.

☐ 4. After locating faulty nozzles, remove and clean. Use new seals. Torque to manufacturer's specifications.

☐ 5. Replace nozzles or test nozzles using the special tools and nozzle tester recommended by manufacturer. Follow engine manufacturer's specifications for torque values, pressure readings, and adjustment methods.

Note: The nozzle is considered leakproof if no fuel emerges at the nipple tip within 10 seconds when testing for leaks.

☐ 6. Install and reconnect fuel lines to injection nozzles according to manufacturer's specifications.

☐ 7. Torque to manufacturer's specifications. Do not overtighten.

☐ 8. Start engine and check for correct operation.

☐ 9. Turn in job ticket when finished.

☐ 10. Clean work area and return tools and materials to proper storage.

Evaluator's Comments: ______________________________

____

____

913

Job Sheet 1

PARTS LIST

QTY.	PARTS/MATERIALS	PRICE	
TOTAL PARTS/MATERIALS			

SPECIFICATIONS CHECKED

School/Work Name ______________________

Address ______________________

Phone # ______________________

Date In ____________

Date Out ____________

JOB TICKET

Customer Name ______________________

Customer Address ______________________

Customer Phone # ______________________

Vehicle/Equip.	Make & Model	License #/Motor #/Serial #	Speedometer

Condition reported by customer/service requested: ______________________

Services/repairs made: ______________________

LABOR	

Customer Authorization

I, the undersigned, have reviewed the required service and parts estimates and authorize this maintenance to be performed with the understanding that I will be notified prior to the performance of any work that significantly exceeds those estimates in time or cost.

______________________ Date ____________

Technician ____________

Supervisor ____________

Objective 25

Job Sheet 2—Isolate, Remove, Test, and Reinstall or Replace Mechanical Unit Injectors

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Directions are followed	______
• Safety procedures are followed	______
• Service manual is used properly	______
• Parts are inspected accurately	______
• Specifications are checked	______
• Faulty injector(s) is located	______
• Adjustments/replacements/repairs are made	______
• Replaced injector(s) works correctly, output correct, no leaks	______
• Job ticket is filled out properly	______
• Cleanup is adequate	______

Basic Skills

Reading · Writing · Science · Critical Thinking · Employability

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, Equipment, and Materials

- Technician's common hand tools
- Appropriate service manuals
- Job ticket or work order—one is included or use appropriate one provided at your facility
- Safety equipment
- Special service tools (or kit) for unit injectors
- Injector vise and rack freeness tester
- Injector tester
- Comparator injector tester or calibrator injector tester
- Injector tube bevel reamer
- Fuel pipe socket
- Torque wrench
- Heel bar
- Clean fuel oil or calibrating oil
- Grease, white
- Clean shop towels (lint-free)
- Cleaning solvent
- Brass wire brush
- Clean bench
- Mechanical fuel injection system with mechanical unit injectors to be worked on
- Others—as recommended by instructor and equipment service manual

9·6

Job Sheet 2

Guidelines

- Unit injectors require careful handling and special service tools.
- Follow special safety precautions when working with unit injectors. The fuel comes out at extremely high pressure which can penetrate clothing and skin and cause injury. Always keep the nozzle pointed away from you or enclose in a beaker when testing.

Procedure

☐ 1. Locate and follow the appropriate procedure in the service manual.

☐ 2. Complete the accompanying job ticket with all pertinent information.

☐ 3. Start engine and bring to operating temperature. Then stop engine.

☐ 4. Remove valve cover(s), and check valve clearance.

☐ 5. To isolate faulty injector(s), start engine again, and hold injector follower down with a screwdriver to prevent operation of the injector.

  ☐ a. If the cylinder is firing (injector is ok), there will be a noticeable difference in sound and rpm when you prevent its operation.

  ☐ b. If the cylinder is misfiring (injector is faulty), there will be no noticeable difference in sound or rpm.

☐ 6. Check all cylinders to determine the faulty injector(s).

☐ 7. Remove the unit injector(s) as outlined in the service manual and mount on fixture.

☐ 8. Perform "pop" test as outlined in the service manual. Additional tests may also be performed if test equipment is available. Check with your instructor to verify which of the following tests are required. Record pressure drop and fuel output readings on the job ticket for tests performed.

  ☐ a. Test injector control rack and plunger movement.

  ☐ b. Test injector valve holding pressure.

  ☐ c. Test injector high pressure.

  ☐ d. Test spray pattern.

  ☐ e. Test fuel output.

☐ 9. Refer to manufacturer's troubleshooting chart and service manuals for additional information if unit injectors do not perform at manufacturer's specifications.

☐ 10. Reinstall unit injectors as outlined in the service manual or replace with new injector(s) as needed.

☐ 11. Refer to service manual for final adjustments, tune-up procedures, and pressure tests for leaks.

☐ 12. Turn in job ticket when finished.

☐ 13. Clean work area and return tools and materials to proper storage.

Evaluator's Comments: ______________________________

____

____

Job Sheet 2

PARTS LIST

QTY.	PARTS/MATERIALS	PRICE	
TOTAL PARTS/MATERIALS			

SPECIFICATIONS CHECKED

School/Work Name ____________________

Address ____________________

Phone # ____________________

Date In __________

Date Out __________

JOB TICKET

Customer Name ____________________

Customer Address ____________________

Customer Phone # ____________________

Vehicle/Equip.	Make & Model	License #/Motor #/Serial #	Speedometer

Condition reported by customer/service requested: ____________________

Services/repairs made: ____________________

LABOR	

Customer Authorization

I, the undersigned, have reviewed the required service and parts estimates and authorize this maintenance to be performed with the understanding that I will be notified prior to the performance of any work that significantly exceeds those estimates in time or cost.

____________________ Date __________

Technician __________

Supervisor __________

Objective 26

Job Sheet 3—Inspect, Test, Adjust, and Time a Distributor-Type (Rotary) Injection Pump; Determine needed repairs

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Directions are followed	______
• Safety procedures are followed	______
• Service manual is used properly	______
• Parts are inspected accurately	______
• Specifications are checked	______
• Adjustments/replacements/repairs are made	______
• Injection pump adjusted and timed correctly	______
• Job ticket is filled out properly	______
• Cleanup is adequate	______

Basic Skills

Reading

Writing

Critical Thinking

Employability

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, Equipment, and Materials

- Technician's common hand tools
- Appropriate service manuals
- Job ticket or work order—one is included or use appropriate one provided at your facility
- Safety equipment
- Pressure gauge
- Timing light/gauge
- Torque wrench
- Clean shop towels (lint-free)
- Mechanical fuel injection system with distributor-type injection pump to be worked on
- Others—as recommended by instructor and equipment service manua

Procedure

☐ 1. Locate and follow the appropriate procedure in the service manual.

☐ 2. Complete the accompanying job ticket with all pertinent information.

☐ 3. Inspect pump and lines for leaks.

☐ 4. Test transfer pump pressure with pressure gauge.

☐ 5. Adjust throttle control linkage and travel as outlined in the service manual.

☐ 6. Check timing using a timing light/gauge as outlined in the service manual. Adjust timing as needed.

☐ 7. Refer to manufacturer's troubleshooting charts and service manuals for additional information if injection pump does not perform at manufacturer's specifications.

☐ 8. Turn in job ticket when finished.

☐ 9. Clean work area and return tools and materials to proper storage.

Evaluator's Comments: ______________________________

____

____

PARTS LIST

QTY.	PARTS/MATERIALS	PRICE	
TOTAL PARTS/MATERIALS			

SPECIFICATIONS CHECKED

School/Work Name ________________
Address ________________
Phone # ________________

Date In ________
Date Out ________

JOB TICKET

Customer Name ________________
Customer Address ________________
Customer Phone # ________________

Vehicle/Equip.	Make & Model	License #/Motor #/Serial #	Speedometer

Condition reported by customer/service requested: ________________

Services/repairs made: ________________

LABOR	

Customer Authorization

I, the undersigned, have reviewed the required service and parts estimates and authorize this maintenance to be performed with the understanding that I will be notified prior to the performance of any work that significantly exceeds those estimates in time or cost.

________________ Date ________

Technician ________
Supervisor ________

Objective 27

Job Sheet 4—Inspect, Test, Adjust, and Time an In-Line Injection Pump; Determine Needed Repairs

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Directions are followed	______
• Safety procedures are followed	______
• Service manual is used properly	______
• Parts are inspected accurately	______
• Specifications are checked	______
• Adjustments/replacements/repairs are made	______
• Injection pump adjusted and timed correctly	______
• Job ticket is filled out properly	______
• Cleanup is adequate	______

Basic Skills

Reading Writing Mathematics Science Oral Communication

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, Equipment, and Materials

- Technician's common hand tools
- Appropriate service manuals
- Job ticket or work order—one is included or use appropriate one provided at your facility
- Safety equipment
- Pressure gauge
- Tachometer
- Torque wrench
- Clean shop towels (lint-free)
- Mechanical fuel injection system with in-line injection pump to be worked on
- Others—as recommended by instructor and equipment service manual

Procedure

☐ 1. Locate and follow the appropriate procedure in the service manual.

☐ 2. Complete the accompanying job ticket with all pertinent information.

☐ 3. Inspect pump and lines for leaks, damage, and wear.

☐ 4. Test transfer pump pressure with pressure gauge.

☐ 5. Adjust throttle control linkage and travel using a tachometer to set speed as outlined in the service manual.

☐ 6. Check timing as outlined in the service manual. Adjust timing as needed.

☐ 7. Refer to manufacturer's troubleshooting charts and service manuals for additional information if injection pump does not perform at manufacturer's specifications.

☐ 8. Turn in job ticket when finished.

☐ 9. Clean work area and return tools and materials to proper storage.

Evaluator's Comments: ______________________________

____

____

PARTS LIST

QTY.	PARTS/MATERIALS	PRICE	
TOTAL PARTS/MATERIALS			

SPECIFICATIONS CHECKED

School/Work Name ______________________
Address ______________________
Phone # ______________________

Date In ____________
Date Out ____________

JOB TICKET

Customer Name ______________________
Customer Address ______________________
Customer Phone # ______________________

Vehicle/Equip.	Make & Model	License #/Motor #/Serial #	Speedometer

Condition reported by customer/service requested: ______________________

Services/repairs made: ______________________

LABOR	

Customer Authorization

I, the undersigned, have reviewed the required service and parts estimates and authorize this maintenance to be performed with the understanding that I will be notified prior to the performance of any work that significantly exceeds those estimates in time or cost.

______________________ Date ____________

Technician ____________
Supervisor ____________

Objective 28

Job Sheet 5—Inspect, Test, and Adjust a PT Injection Pump and Time the Injectors; Determine Needed Repairs

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Directions are followed	______
• Safety procedures are followed	______
• Service manual is used properly	______
• Parts are inspected accurately	______
• Specifications are checked	______
• Adjustments/replacements/repairs are made	______
• Injection pump adjusted correctly	______
• Injectors timed correctly	______
• Job ticket is filled out properly	______
• Cleanup is adequate	______

Basic Skills

Reading Writing Critical Thinking Employability

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, Equipment, and Materials

- Technician's common hand tools
- Appropriate service manuals
- Job ticket or work order—one is included or use appropriate one provided at your facility
- Safety equipment
- Injector rocker lever actuator
- Pressure gauge
- Tachometer
- Torque wrench
- Clean shop towels (lint-free)
- Mechanical fuel injection system with PT injection pump to be worked on
- Others—as recommended by instructor and equipment service manual

Procedure

☐ 1. Locate and follow the appropriate procedure in the service manual.

☐ 2. Complete the accompanying job ticket with all pertinent information.

☐ 3. Isolate any faulty injectors by holding the injector plunger down with an injector rocker lever actuator. This prevents the injector from operating. Listen for a change in engine speed.

  ☐ a. If sound and rpm change, injector is ok.

  ☐ b. If sound and rpm do not change, the injector is faulty.

☐ 4. Replace faulty injectors as outlined in the service manual.

☐ 5. Inspect pump high pressure injection lines, hold downs, fittings, and seals for leaks, damage, and wear.

☐ 6. Test pressure with pressure gauge.

☐ 7. Adjust timing by adjusting injector plunger, valves, and injectors as outlined in the service manual.

☐ 8. Check governor's low idle speed and engine maximum no-load speed as outlined in the fuel service manual.

☐ 9. Refer to manufacturer's troubleshooting charts and service manuals for additional information if injection pump and injectors do not perform at manufacturer's specifications.

☐ 10. Turn in job ticket when finished.

☐ 11. Clean work area and return tools and materials to proper storage.

Evaluator's Comments: ________________________________

____

____

930

PARTS LIST

QTY.	PARTS/MATERIALS	PRICE	
TOTAL PARTS/MATERIALS			

SPECIFICATIONS CHECKED

School/Work Name ____________________

Address ____________________

Phone # ____________________

Date In __________

Date Out __________

JOB TICKET

Customer Name ____________________

Customer Address ____________________

Customer Phone # ____________________

Vehicle/Equip.	Make & Model	License #/Motor #/Serial #	Speedometer

Condition reported by customer/service requested: ____________________

Services/repairs made: ____________________

LABOR

Customer Authorization

I, the undersigned, have reviewed the required service and parts estimates and authorize this maintenance to be performed with the understanding that I will be notified prior to the performance of any work that significantly exceeds those estimates in time or cost.

____________________ Date __________

Technician __________

Supervisor __________

Job Sheet 5

Electronic Fuel Injection Diagnosis and Repair

Unit Contents

Student Components

Student Page

Objective Sheet 3C-3

Information Sheet 3C-5

Student Supplement

1—SAE Fault Codes 3C-17

Job Sheets

1—Inspect and Test Power and Ground Circuits and Connections; Determine Needed Repairs 3C-19
2—Check Diagnostic Trouble Codes Using Scan Tools and Technical Information; Determine Needed Repairs 3C-23
3—Inspect and Replace Electrical Connectors, Terminals, Seals, and Locks 3C-27
4—Access Engine Parameters; Monitor or Change as Requested by Customer 3C-31
5—Remove, Inspect, and Rebuild or Replace a Fuel Transfer Pump 3C-35
6—Remove, Inspect, Reinstall, and Adjust Electronic Unit Injectors; Determine Needed Repairs 3C-39

933

Unit 3-C

Electronic Fuel Injection Diagnosis and Repair

Objective Sheet

Unit Objective

After completing this unit, the student should be able to identify the basic parts of an electronic fuel injection system, as well as be able to inspect, test, and replace common electronic fuel injection components. The student should demonstrate these competencies by completing the job sheets and by scoring a minimum of 85 percent on the written test.

Specific Objectives

After completing this unit, the student should be able to:

1. Match terms related to electronic fuel injection with their definitions.
2. Identify the parts of a typical electronic fuel system.
3. Arrange in order the steps describing the fuel flow through an electronic fuel system.
4. Identify the parts of an electronic unit injector.
5. Describe the advantages of electronic fuel injection over mechanical fuel injection.
6. Identify common types of electronic fuel injection systems.
7. Distinguish among the basic categories of electronic components.
8. List common electronic sensors.
9. Describe the meanings of common electronic acronyms or abbreviations.
10. Match specialty tools and equipment used for electronic diagnosis with their descriptions.
11. List basic types of diagnostic codes.
12. Distinguish between standardized SAE and non-standardized electronic message identification codes.
13. Inspect and test power and ground circuits and connections; determine needed repairs. (Job Sheet 1)
14. Check diagnostic trouble codes using scan tools and technical information; determine needed repairs. (Job Sheet 2)
15. Inspect and replace electrical connectors, terminals, seals, and locks. (Job Sheet 3)
16. Access engine parameters; monitor or change as requested by customer. (Job Sheet 4)

Objective Sheet

17. Remove, inspect, and rebuild or replace a fuel transfer pump. (Job Sheet 5)

18. Remove, inspect, reinstall, and adjust electronic unit injectors; determine needed repairs. (Job Sheet 6)

Information Sheet

Objective 1

Terms and definitions

a. **Active codes**—Codes describing condition that is currently present to alert driver or service technician of abnormal parameters

b. **Actuator**—Device that performs work in response to an electronic signal

c. **Bypass circuit**—Circuit, usually temporary, used to substitute for an existing circuit, typically for test purposes

d. **Calibration**—Adjustment of a sensor signal

e. **Computer data link**—Connection between two electronic devices for communication purposes; used for programming and troubleshooting

f. **Data**—Information in numerical form that can be digitally transmitted or processed

g. **Diagnostic code**—Digital readout that identifies a problem or event in an electronic system

Note: This may also be called a fault code or trouble code.

h. **Driver**—Transistor in the output section of the ECM used to turn on or off various actuators in the system

i. **Electronic control module (ECM)**—Computerized device that monitors other electronic parts and acts as a governor in electronic fuel systems

Note: This is the "brains" or command center for the electronic system.

j. **Harness**—Wiring bundle connecting all electronic components

k. **Historical or inactive codes**—Codes stored in ECM memory

l. **Microprocessor**—Integrated circuit within a microcomputer that controls information flow within the computer

m. **On-demand test**—Self test that the technician initiates; run from a program in the processor

n. **Parameter**—Programmable value that affects the characteristics or behavior of the engine and/or vehicle

Examples: High idle RPM, idle speed, PTO speed

o. **Personality module**—Electronic module that stores individual vehicle parameters for the system being used

Note: This module allows for several vehicle features to be reset, such as road speed, cruise control set points, and speedometer calibrations.

p. **Potentiometer**—Electro-mechanical device that senses the position of a mechanical component

q. **Pulse width**—Length of time an actuator, such as an injector, remains energized

r. **Random access memory (RAM)**—Type of memory used to store information; can be written to and read from

s. **Read only memory (ROM)**—Type of memory used to store information permanently; cannot be written over

t. **Reference voltage**—Regulated voltage supplied by the electronic control module to a sensor; used by sensor to generate a signal voltage

u. **Sensor**—Device used to detect and convert a change in a measurement (such as pressure, temperature, or movement) into an electrical signal

v. **Signal**—Voltage or waveform used to transmit information, usually from a sensor to the electronic control module

w. **Solenoid**—Electronic device that controls the amount of fuel delivered by the injector

x. **Thermistor**—Sensor used to determine temperature

y. **Threshold value**—Value stored in the ROM portion of the ECM which is used for comparison to a sensor's value

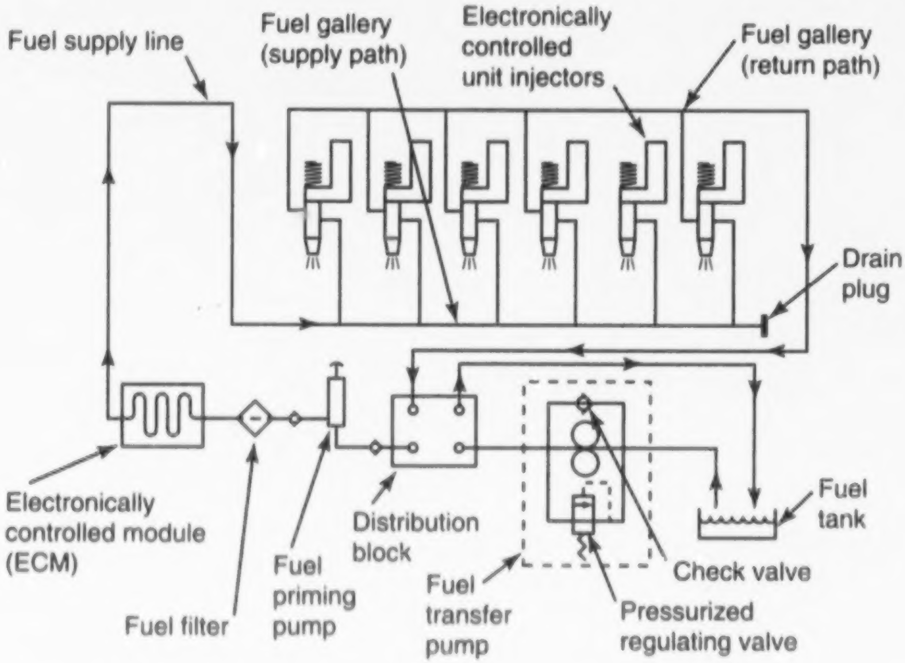
Note: If the value is not within the parameters of the threshold value, a service code is recorded.

z. **Transducer**—Device that converts a mechanical signal to an electrical signal; used to sense pressure

Objective 2

Parts of a typical electronic fuel system

Figure 1


Fuel supply line
Fuel gallery (supply path)
Electronically controlled unit injectors
Fuel gallery (return path)
Drain plug
Electronically controlled module (ECM)
Fuel filter
Fuel priming pump
Distribution block
Fuel transfer pump
Check valve
Pressurized regulating valve
Fuel tank

© Caterpillar Inc. Used with permission

Objective 3

Fuel flow through an electronic fuel system

a. Fuel is drawn from tank through a possible primary fuel filter (or strainer) and enters the fuel transfer pump.

b. Fuel then goes through possible distribution block, priming pump, secondary fuel filter, cooler plate on ECM, and to the cylinder head inlet passage.

c. Fuel is sent to injectors.

d. ECM senses timing and sends signal to injector solenoid to energize it.

e. Energized solenoid opens fuel flow through injector body which is pushed by plunger operated by cam lobe on engine.

f. Fuel is pushed down to injection nozzle and then is sprayed into combustion chamber under very high pressure.

g. ECM deenergizes solenoid which shuts off fuel.

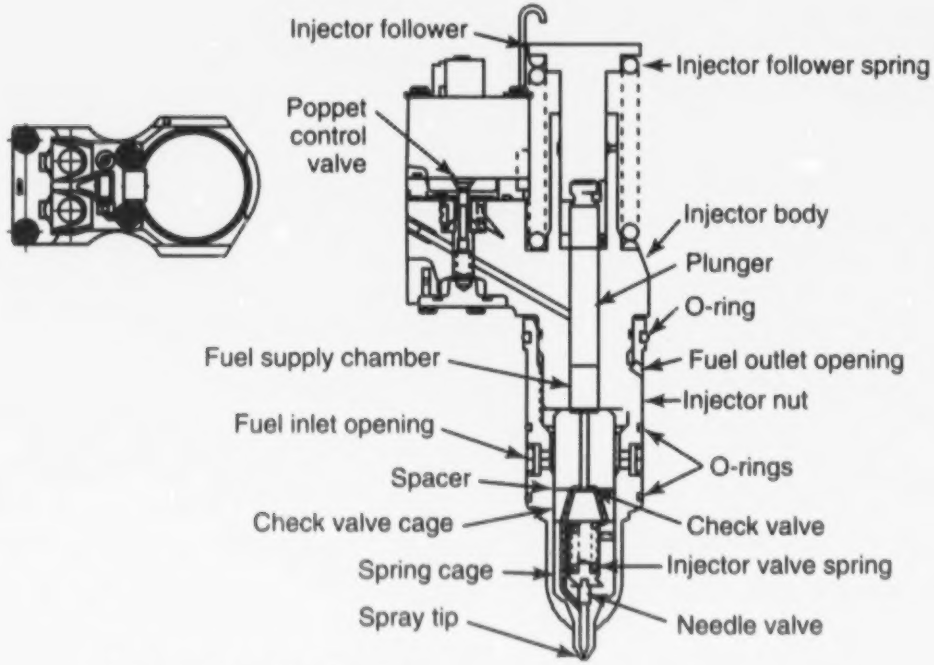
h. Cam lobe rotates allowing plunger to lift, ready for next stroke.

i. Return fuel from injector is routed back to fuel tank.

Objective 4

Parts of an electronic unit injector

Figure 2


Injector follower
Injector follower spring
Poppet control valve
Injector body
Plunger
O-ring
Fuel supply chamber
Fuel outlet opening
Injector nut
Fuel inlet opening
O-rings
Spacer
Check valve cage
Check valve
Spring cage
Injector valve spring
Spray tip
Needle valve

Courtesy of Detroit Diesel Corporation

Objective 5

Advantages of electronic fuel injection over mechanical fuel injection

a. Improved engine governing, timing, and fuel/air ratios

b. Improved engine performance

c. Reduced fuel consumption

d. Reduced emission levels

e. Enhanced cold starting

f. Improved diagnosis of engine malfunctions resulting in:

- Reduced troubleshooting (down) time
- Reduced labor costs

g. Increased flexibility

- Parameters can be changed electronically, instead of manually.
- Parameters can be changed so vehicle can operate at different loads, altitudes, and terrains.

h. Improved engine protection

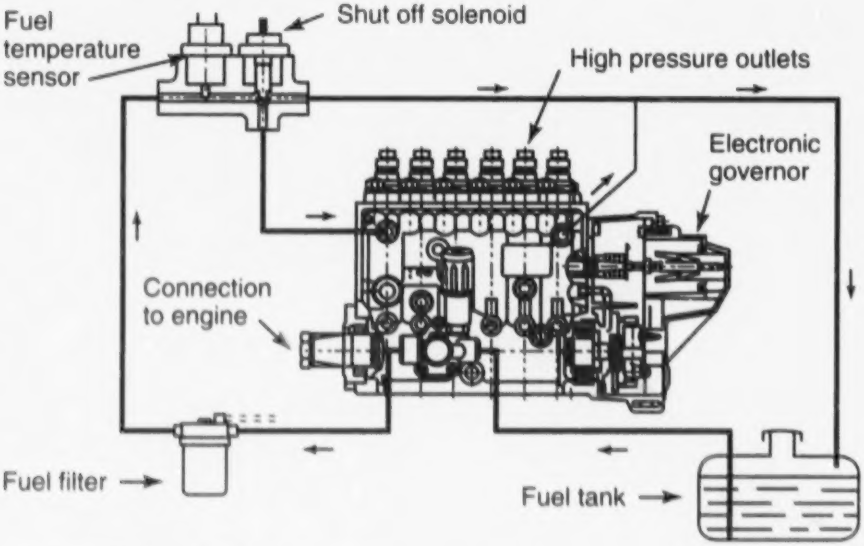
- Engine can be programmed to shutdown before dangerous limits are reached.
- System is more tamper resistant with multilevel security.
- Engine warm-up can be programmed.

Objective 6

Common types of electronic fuel injection systems

a. In-line injection pump with electronic governor

Figure 3

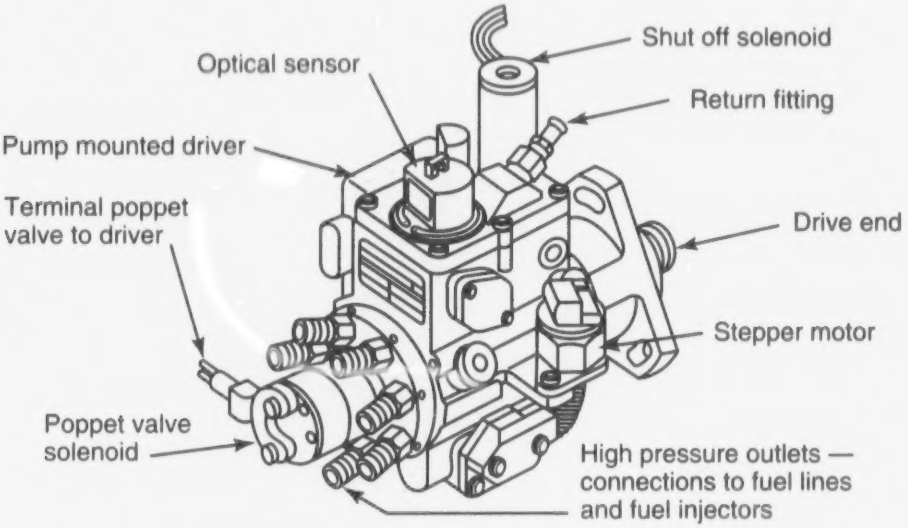

Fuel temperature sensor
Shut off solenoid
High pressure outlets
Electronic governor
Connection to engine
Fuel filter
Fuel tank

Courtesy of Robert Bosch Corporation

940

b. Distributor-type injection pump with electronic governor

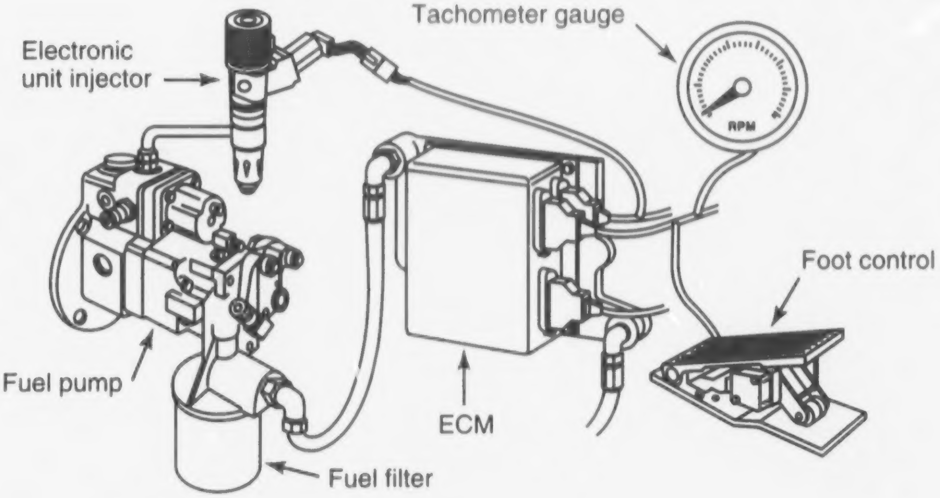
Figure 4


Shut off solenoid
Optical sensor
Return fitting
Pump mounted driver
Terminal poppet valve to driver
Drive end
Stepper motor
Poppet valve solenoid
High pressure outlets — connections to fuel lines and fuel injectors

Courtesy of General Motors Corporation

c. Electronic unit injectors

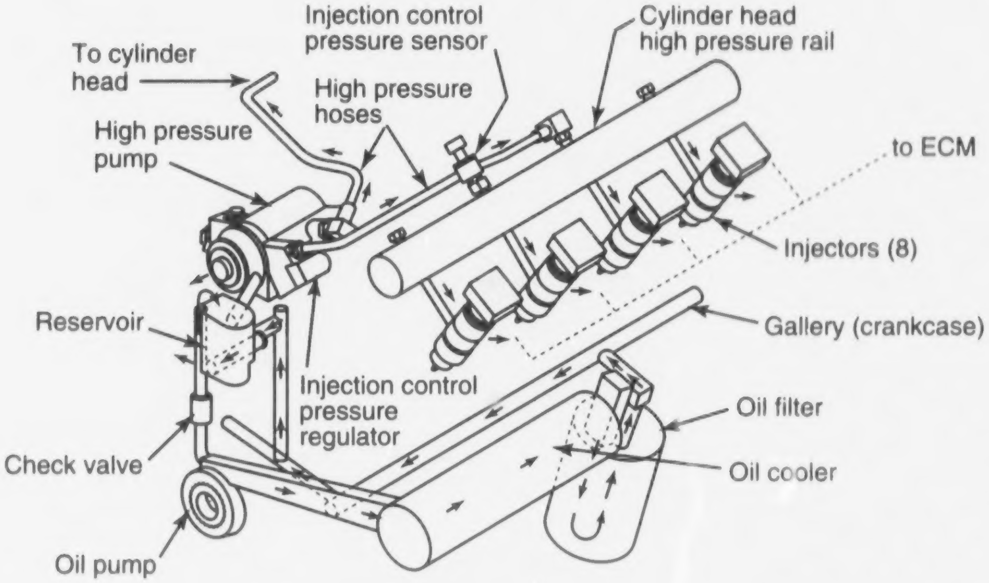
Figure 5


Tachometer gauge
Electronic unit injector
RPM
Foot control
Fuel pump
ECM
Fuel filter

Courtesy of Cummins Engine Company, Inc.

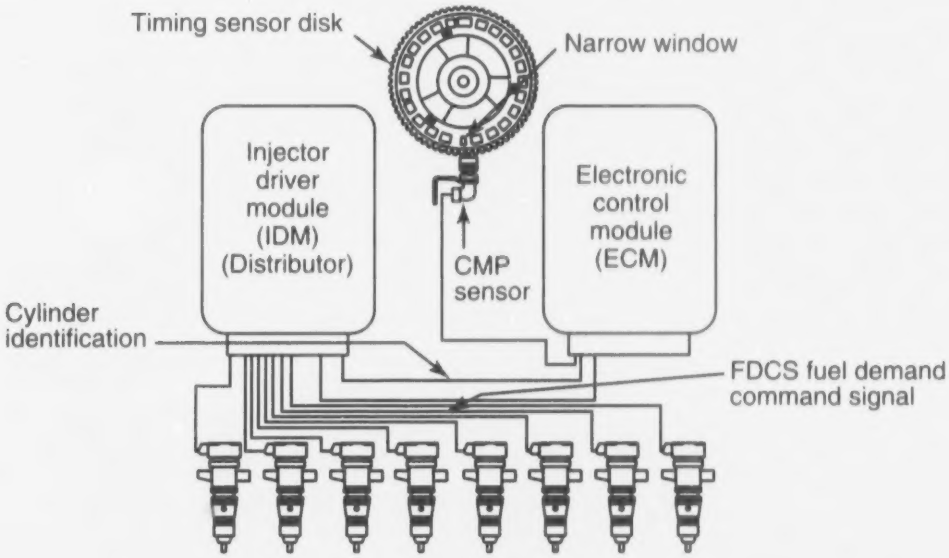
d. Hydraulically-operated and electronically-controlled unit injectors (HEUI)

Figure 6—Hydraulic part


To cylinder head
Injection control pressure sensor
Cylinder head high pressure rail
High pressure hoses
High pressure pump
to ECM
Injectors (8)
Reservoir
Gallery (crankcase)
Injection control pressure regulator
Oil filter
Check valve
Oil cooler
Oil pump

Courtesy of Navistar International Transportation Corp.

Figure 7—Electronic part


Timing sensor disk
Narrow window
Injector driver module (IDM) (Distributor)
Electronic control module (ECM)
CMP sensor
Cylinder identification
FDCS fuel demand command signal

Courtesy of Navistar International Transportation Corp.

Objective 7

Basic categories of electronic components

a. **Input components**

- Includes sensors and switches
- Sends electrical signals to the ECM

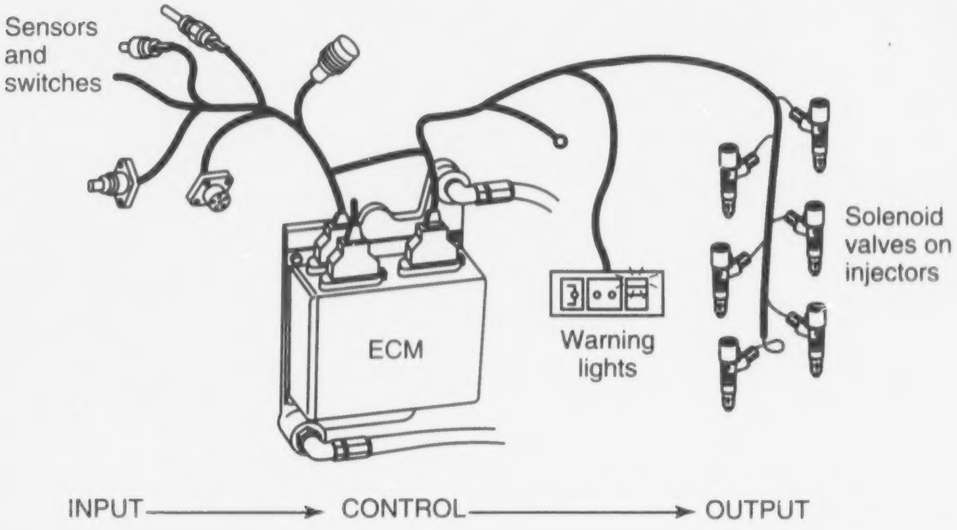
b. **Control component—Electronic control module (ECM)**

- Contains the microcomputer, voltage reference regulator, input conditioners, and output drivers
- Receives input signals and sends output signals

c. **Output components**

- Includes electronic components that perform work, such as solenoids, and electrical warning devices
- Receives electrical signals from ECM

Figure 8


Sensors and switches
ECM
Warning lights
Solenoid valves on injectors
INPUT → CONTROL → OUTPUT

Objective 8

Common electronic sensors

a. Atmospheric pressure sensor

b. Boost pressure sensor (inlet manifold air pressure)

c. Coolant level sensor

d. Coolant temperature sensor

e. Engine speed/timing sensor

f. Fuel temperature sensor

g. Intake manifold air temperature sensor

h. Oil pressure sensor

i. Oil temperature

j. Synchronous reference

k. Throttle position sensor

l. Timing reference

m. Vehicle speed sensor (rotation of gear teeth in drive train)

Objective 9

Common electronic acronyms or abbreviations and their meanings

a. CEL—"Check engine" light

b. CELECT—Cummins electronically controlled fuel injection system

c. DDEC—Detroit Diesel electronic control

d. DDL—Diagnostic data link

e. DDR—Diagnostic data reader

f. ECAP—Electronic control analyzer and programmer (Caterpillar)

g. ECM—Electronic control module

h. ECUI—Electronically controlled unit injector

i. EDU—Electronic distributor unit

j. EEPROM—Electronically erasable programmable read only memory

k. EUI—Electronic unit injector

l. HEUI—Hydraulically actuated, electronically controlled, unit injectors

m. ICM—Ignition control module

n. IDM—Ignition driver module (distributor)

o. IPR—Injection pressure regulator

p. PROM—Programmable read only memory

q. SEL—"Stop engine" light

Objective 10

Specialty tools and equipment used for electronic diagnosis

a. **Adapter cables, breakout T cables, and probes**—Used with service tools in order to access measurements of signals

b. **Brass brush for electronic injection nozzle tips**—For cleaning nozzle tips

c. **Diagnostic jumper wires**—Used for jumping terminals when troubleshooting

d. **Digital multimeter (or DVOM)**—Used for checking voltages and resistance

e. **Electronic service (scan) tool**—Hand-held scanning device used to access diagnostic and programming information in order to locate problems in the electronic system

f. **Injector tube installation/removal tools**—Used to replace defective injector tubes

g. **Oscilloscope**—Used for visually checking the amount of voltage by observing visible wave forms on a fluorescent screen

h. **Personal computer (PC) with diagnostic software**—Used to read diagnostic codes, change parameters, and obtain engine monitoring information

i. **PROM removal tool**—Used for removing defective memory chips or upgrading memory chips

j. **Terminal crimping tool**–Used for replacing ends on wiring harnesses

k. **Terminal removal tool**—Used for pulling defective terminals

l. **Testing harness**—Typically inserted between two ends of a connector to permit normal circuit operation while measuring voltages

Objective 11

Basic types of diagnostic codes

a. Cylinder faults

b. Injector faults

c. Temperature out of normal range

d. Pressure out of normal range

e. Speeds out of normal range

f. Fluid levels below normal

g. Voltage above or below normal or shorted

h. Current above or below normal, open, or grounded

Objective 12

Electronic identification message codes

a. **SAE fault codes**—Standardized throughout the industry to identify electronic problems (Student Supplement 1)

- MID—Message Identifier

  Note: This identifies the communication device sending the message. For example, MID 128 identifies the diesel engine as the communication device.

- FMI—Failure Mode Identifier
- SID—System (or Subsystem) Identifier
- PID—Parameter Identifier

  Note: The FMI, SID, and PID narrow down the problem area to a specific sensor or other electronic output device. This will tell the service technician where to start.

b. **Flash codes**—Non-standardized numbering system developed by different manufacturers to identify electronic problems

Example: DDECIII flash code 66 identifies an engine knock sensor input fault.

Student Supplement 1—SAE Fault Codes

SAE Faults	
p051 0	Throttle valve position above normal range
p051 1	Throttle valve position below normal range
p051 3	Throttle valve input voltage high
p051 4	Throttle valve input voltage low
p051 7	Throttle valve not responding
p052 0	Intercooler temperature high
p052 3	Intercooler sensor input voltage high
p052 4	Intercooler sensor input voltage low
p070 4	Optimized idle safety loop short to ground
p072 3	Bypass position sensor input voltage high
p072 4	Bypass position sensor input voltage low
p073 0	External pump pressure high
p073 3	Pump pressure sensor input voltage high
p073 4	Pump pressure sensor input voltage low
p084 0	Vehicle overspeed (fueled)
p084 11	Vehicle overspeed (absolute)
p084 12	Vehicle speed sensor failure
p091 3	Throttle position sensor input voltage high
p091 4	Throttle position sensor input voltage low
p092 0	Torque overload
p094 0	Fuel pressure high
p094 1	Fuel pressure low
p094 3	Fuel pressure sensor input voltage high
p094 4	Fuel pressure sensor input voltage low
p098 0	Oil level high
p098 1	Oil level low
p098 3	Oil level sensor input voltage high
p098 4	Oil level sensor input voltage low
p100 1	Oil pressure low
p100 3	Oil pressure sensor input voltage high
p100 4	Oil pressure sensor input voltage low
p101 0	Crankcase pressure high
p101 1	Crankcase pressure low
p101 3	Crankcase pressure sensor input voltage high
p101 4	Crankcase pressure sensor input voltage low
p102 0	Turbo boost pressure high
p102 3	Turbo boost pressure sensor input voltage high
p102 4	Turbo boost pressure sensor input voltage low
p103 8	Turbo speed sensor input failure
p105 0	Intake air temperature high
p105 3	Intake air temp. sensor input voltage high
p105 4	Intake air temp. sensor input voltage low
p106 0	Air inlet pressure high
p106 1	Air inlet pressure low
p106 3	Air inlet pressure sensor input voltage high
p106 4	Air inlet pressure sensor input voltage low
p108 3	Baro. pressure sensor input voltage high
p108 4	Baro. pressure sensor input voltage low
p109 1	Coolant pressure low
p109 3	Coolant pressure sensor input voltage high
p109 4	Coolant pressure sensor input voltage low
p110 0	Coolant temperature high
p110 3	Coolant temp. sensor input voltage high
p110 4	Coolant temp. sensor input voltage low

SAE Faults	
p111 1	Coolant level low
p111 3	Coolant level sensor input voltage high
p111 4	Coolant level sensor input voltage low
p121 0	Engine overspeed with engine brake
p168 0	ECM battery voltage high
p168 1	ECM battery voltage low
p172 3	Air temperature sensor input voltage high
p172 4	Air temperature sensor input voltage low
p173 0	Exhaust temperature high
p173 3	Exhaust temperature sensor input voltage high
p173 4	Exhaust temperature sensor input voltage low
p174 3	Fuel temperature sensor input voltage high
p174 4	Fuel temperature sensor input voltage low
p175 0	Oil temperature high
p175 3	Oil temperature sensor input voltage high
p175 4	Oil temperature sensor input voltage low
p187 3	VSG sensor input voltage high
p187 4	VSG sensor input voltage low
p187 7	VSG switch system not responding
p190 0	Engine overspeed
p251 10	Clock module abnormal rate
p251 13	Clock module fault
s001 0	Injector #1 response time long
s001 1	Injector #1 response time short
s002 0	Injector #2 response time long
s002 1	Injector #2 response time short
s003 0	Injector #3 response time long
s003 1	Injector #3 response time short
s004 0	Injector #4 response time long
s004 1	Injector #4 response time short
s005 0	Injector #5 response time long
s005 1	Injector #5 response time short
s006 0	Injector #6 response time long
s006 1	Injector #6 response time short
s007 0	Injector #7 response time long
s007 1	Injector #7 response time short
s008 0	Injector #8 response time long
s008 1	Injector #8 response time short
s009 0	Injector #9 response time long
s009 1	Injector #9 response time short
s010 0	Injector #10 response time long
s010 1	Injector #10 response time short
s011 0	Injector #11 response time long
s011 1	Injector #11 response time short
s012 0	Injector #12 response time long
s012 1	Injector #12 response time short
s013 0	Injector #13 response time long
s013 1	Injector #13 response time short
s014 0	Injector #14 response time long
s014 1	Injector #14 response time short
s015 0	Injector #15 response time long
s015 1	Injector #15 response time short
s016 0	Injector #16 response time long

Student Supplement 1

SAE Faults	
s016 1	Injector #16 response time short
s020 3	Duel fuel BOI input voltage high
s020 4	Duel fuel BOI input voltage low
s021 0	Too many SRS (missing TRS)
s021 1	Too few SRS (missing SRS)
s025 11	Auxiliary engine shutdown #1 input active
s040 7	Auxiliary Output #2 Mech. System not responding properly
s047 0	Injector #17 response time long
s047 1	Injector #17 response time short
s048 0	Injector #18 response time long
s048 1	Injector #18 response time short
s049 0	Injector #19 response time long
s049 1	Injector #19 response time short
s050 0	Injector #20 response time long
s050 1	Injector #20 response time short
s051 3	Auxiliary Output #3 open circuit
s051 4	Auxiliary Output #3 short to ground
s052 3	Auxiliary Output #4 open circuit
s052 4	Auxiliary Output #4 short to ground
s053 3	Auxiliary Output #5 short to battery (+)
s053 4	Auxiliary Output #5 open circuit
s053 7	Auxiliary Output #5 Mech. System not responding properly
s054 3	Auxiliary Output #6 short to battery (+)
s054 4	Auxiliary Output #6 open circuit
s054 7	Auxiliary Output #6 Mechanical System not responding properly
s055 3	Auxiliary Output #7 short to battery (+)
s055 4	Auxiliary Output #7 open circuit
s055 7	Auxiliary Output #7 Mechanical System not responding properly
s056 3	Auxiliary Output #8 short to battery (+)
s056 4	Auxiliary Output #8 open circuit
s056 7	Auxiliary Output #8 Mechanical System not responding properly
s057 3	PWM driver #1 short to battery (+)
s057 4	PWM driver #1 open circuit
s058 3	PWM driver #2 short to battery (+)
s058 4	PWM driver #2 open circuit
s059 3	PWM driver #3 short to battery (+)
s059 4	PWM driver #3 open circuit
s060 3	PWM driver #4 short to battery (+)
s060 4	PWM driver #4 open circuit
s061 11	Auxiliary engine shutdown #2 input active
s072 0	#21 Injector response time long
s072 1	#21 Injector response time short
s073 0	#22 Injector response time long
s073 1	#22 Injector response time short
s074 0	#23 Injector response time long
s074 1	#23 Injector response time short
s075 0	#24 Injector response time long
s075 1	#24 Injector response time short
s076 0	Engine knock level above normal range
s076 3	Engine knock sensor input voltage high
s076 4	Engine knock sensor input voltage low
s076 7	Engine knock sensor torque reduction
s077 0	Gas valve position above normal range
SAE Faults	
s077 1	Gas valve position below normal range
s077 3	Gas valve position input voltage high
s077 4	Gas valve position input voltage low
s151 14	System Diagnostic Code #1 (ESS)
s226 11	Transmission Neutral Switch (ESS)
s227 4	Auxiliary Analog Input #1 voltage low (ESS)
s227 3	Auxiliary Analog Input #1 voltage high (ESS)
s227 2	Auxiliary Analog Input #1 data erratic, intermittent, or incorrect (ESS)
s230 5	TPS idle validation switch open circuit
s230 6	TPS idle validation switch short to ground
s231 12	J1939 data link fault
s238 3	SEL short to battery (+)
s238 4	SEL open circuit
s239 3	CEL short to battery (+)
s239 4	CEL open circuit
s240 2	Fram checksum incorrect
s248 8	Proprietary data link fault (master)
s248 9	Proprietary data link fault (slave)
s249 12	J1922 data link fault
s250 12	J1587 data link fault
s253 2	Non volatile memory data incorrect
s253 12	Non volatile memory fault
s253 13	Incompatible calibration version
s254 0	External failed RAM
s254 1	Internal failed RAM
s254 6	Entered boot via switches
s254 12	ECM A/D Conversion fail

948

Objective 13

Job Sheet 1—Inspect and Test Power and Ground Circuits and Connections; Determine Needed Repairs

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Directions are followed	______
• Safety procedures are followed	______
• Parts are inspected accurately	______
• Specifications are checked	______
• Job ticket is filled out properly	______
• Cleanup is adequate	______

Basic Skills

Reading Writing Science Critical Thinking Employability

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, Equipment, and Materials

- Technician's common hand tools
- Appropriate service manual
- Job ticket or work order—one is included or use appropriate one provided at your facility
- Digital multimeter or voltohmmeter (DVOM)
- OEM jumper wires or test leads with various tips (alligator clips, probe tips, terminal tips)
- Electronic system to be worked on—assigned by instructor
- Others—as recommended by instructor and equipment service manual

Note: Only use approved electronic testing tools.

Procedure

☐ 1. Locate and follow the appropriate procedure in the service manual.

☐ 2. Complete the accompanying job ticket with all pertinent information.

☐ 3. Inspect for corroded terminals, loose connections, and damaged wires. Determine needed repairs.

☐ 4. Check that voltage is present to power a device in an electrical circuit using a digital multimeter or voltmeter.

  ☐ a. Connect the positive meter lead to input connection of device (positive side) and connect negative meter lead to good vehicle ground.

  Note: Meter is connected in parallel to the device.

  ☐ b. This will show how much of the source voltage is available to the device.

☐ 5. Check for voltage drop across a load device using a digital multimeter or voltmeter.

  ☐ a. Connect the positive lead of the voltmeter to the positive side of the device and the negative meter lead to the negative side of the device.

  ☐ b. With the device working, all of the voltage should be dropped (12V in a 12V system). If not all of the voltage drops, (for example, 9V in a 12V system) there is a problem such as corroded or loose connections or components.

  Note: By taking voltage drop readings in various parts of the circuit, the problem can be isolated.

☐ 6. Check for open circuits using a digital multimeter or ohmmeter.

  ☐ a. Disconnect circuit from power supply.

  ☐ b. Disconnect circuit from other circuits in order to isolate it.

  ☐ c. Connect the meter to the open ends of the circuit.

  ☐ d. Read meter. A high reading (infinity) indicates there is an open in the circuit. A near zero reading indicates a continuous circuit.

☐ 7. Check for short circuits using a digital multimeter or ohmmeter.

  ☐ a. Disconnect circuit from power source and ground point.

  ☐ b. Connect one end of the meter to one end of isolated circuit. Connect the other end of the meter to a good ground point.

  ☐ c. Read meter. A near zero reading indicates a short to ground. A very high reading (near infinity) indicates a circuit not shorted to ground.

950

Note: Jumper wires may also be used to check for open circuits, faulty components, and poor connections.

☐ 8. Turn in job ticket when finished.

☐ 9. Clean work area and return tools and materials to proper storage.

Evaluator's Comments: ____

____

____

PARTS LIST

QTY.	PARTS/MATERIALS	PRICE	
TOTAL PARTS/MATERIALS			

SPECIFICATIONS CHECKED

School/Work Name ____________________

Address ____________________

Phone # ____________________

Date In ____________

Date Out ____________

JOB TICKET

Customer Name ____________________

Customer Address ____________________

Customer Phone # ____________________

Vehicle/Equip.	Make & Model	License #/Motor #/Serial #	Speedometer

Condition reported by customer/service requested: ____________________

Services/repairs made: ____________________

LABOR	

Customer Authorization

I, the undersigned, have reviewed the required service and parts estimates and authorize this maintenance to be performed with the understanding that I will be notified prior to the performance of any work that significantly exceeds those estimates in time or cost.

____________________ Date ____________

Technician ____________

Supervisor ____________

Objective 14

Job Sheet 2—Check Diagnostic Trouble Codes Using Electronic Diagnostic Equipment and Technical Information; Determine Needed Repairs

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Directions are followed	______
• Safety procedures are followed	______
• Electronic equipment is used properly	______
• Service manual is used properly	______
• Trouble codes are correctly identified	______
• Parts are inspected accurately	______
• Specifications are checked	______
• Job ticket is filled out properly	______
• Cleanup is adequate	______

Basic Skills

Reading Writing Science Critical Thinking Employability

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, Equipment, and Materials

- Technician's common hand tools
- Appropriate service manual, including explanation of diagnostic codes
- Job ticket or work order—one is included or use appropriate one provided at your facility
- Electronic diagnostic equipment—designed or adapted for vehicle
  - — Scan tool/digital reader or
  - — Personal computer (PC) with appropriate software
- Appropriate electronic adapters
- Digital voltohmmeter (DVOM)
- Electronic fuel injection system to be worked on
- Others—as recommended by instructor and equipment service manua

Procedure

☐ 1. Locate and follow the appropriate procedure in the service manual.

Note: Although the general procedure for checking trouble codes is similar for most manufacturers, different equipment, software, and adapters will be used. Also different abbreviations and code numbers will be used. Always follow the service manual.

☐ 2. Complete the accompanying job ticket with all pertinent information.

☐ 3. Turn ignition off.

☐ 4. Check terminals at all ECM connectors for damage, corrosion, and unseated pins or sockets.

☐ 5. Plug in the multi-pin wiring connectors/adapters for the diagnostic equipment to be used.

Note: If diagnostic equipment is not available, check the troubleshooting manual in order to read "Check Engine Light" flashing codes.

☐ 6. Turn on diagnostic equipment.

☐ 7. Turn on vehicle's ignition switch.

☐ 8. Follow scan tool's instructions or computer prompts to read the active codes on the diagnostic tool readout. List codes being registered on job ticket. Clear and retest to see if codes come back.

☐ 9. Refer to the manufacturer's troubleshooting manuals for explanation of codes and possible causes of trouble. Record troubleshooting procedure followed (and page numbers) on job ticket.

☐ 10. Use digital voltohmmeter (DVOM) to verify sensor readings.

☐ 11. Replace faulty components (sensors, actuators, etc.) as outlined in the service manual.

☐ 12. Recheck diagnostic tool to make sure problem was solved.

☐ 13. Monitor active codes, and check vehicle operation to make sure all problems are solved.

☐ 14. Disconnect diagnostic equipment and reconnect appropriate electrical connectors, if necessary.

☐ 15. Turn in job ticket when finished.

☐ 16. Clean work area and return tools and materials to proper storage.

Evaluator's Comments: ______________________________

____

____

PARTS LIST

QTY.	PARTS/MATERIALS	PRICE	
TOTAL PARTS/MATERIALS			

SPECIFICATIONS CHECKED

School/Work Name ____________________
Address ____________________
Phone # ____________________

Date In ____________
Date Out ____________

JOB TICKET

Customer Name ____________________
Customer Address ____________________
Customer Phone # ____________________

Vehicle/Equip.	Make & Model	License #/Motor #/Serial #	Speedometer

Condition reported by customer/service requested: ____________________

Services/repairs made: ____________________

LABOR	

Customer Authorization

I, the undersigned, have reviewed the required service and parts estimates and authorize this maintenance to be performed with the understanding that I will be notified prior to the performance of any work that significantly exceeds those estimates in time or cost.

____________________ Date ____________

Technician ____________
Supervisor ____________

Objective 15

Job Sheet 3—Inspect and Replace Electrical Connectors, Terminals, Seals, and Locks

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Directions are followed	______
• Safety procedures are followed	______
• Service manual is used properly	______
• Parts are inspected accurately	______
• Specifications are checked	______
• Adjustments/replacements/repairs are made	______
• Job ticket is filled out properly	______
• Cleanup is adequate	______

Basic Skills

Reading Writing Science Critical Thinking Employability

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, Equipment, and Materials

- Technician's common hand tools
- Appropriate service manual, including explanation of diagnostic codes
- Job ticket or work order—one is included or use appropriate one provided at your facility
- Eye protection
- Special connector repair tools as required
- Wire stripping and crimping tool
- Appropriate replacement connectors, terminals, seals, and locks
- Razor blade or cleaning flux solution
- Soldering iron or gun
- Rosin core solder
- Wet sponge
- Digital multimeter or voltohmmeter (DVOM)
- Junk engine harness
- Electrical system to be worked on
- Others—as recommended by instructor and equipment service manual

Procedure

☐ 1. Locate and follow the appropriate procedure in the service manual.

☐ 2. Complete the accompanying job ticket with all pertinent information.

☐ 3. Inspect for damaged or corroded connectors and terminals and loose connections.

☐ 4. Remove any damaged or corroded parts. Follow manufacturer's instructions for special tools required.

☐ 5. Cut off the old terminal or bad section of wire.

☐ 6. Strip insulation from end of wire using suitable stripping tool. Be careful not to cut or nick the wire strands.

☐ 7. Position exposed wiring in new connector or terminal and crimp with suitable crimping tool.

☐ 8. Tug slightly on wire to verify that contact is properly secured.

☐ 9. Solder the crimped terminals if allowed by OEM and electrically check for continuity.

☐ 10. Cover splices or other connections with splice tape, insulation, seals, or locks as specified by manufacturer.

☐ 11. Turn in job ticket when finished.

☐ 12. Clean work area and return tools and materials to proper storage.

Evaluator's Comments: ______________________________

____

____

Job Sheet 3

PARTS LIST

QTY.	PARTS/MATERIALS	PRICE	
TOTAL PARTS/MATERIALS			

SPECIFICATIONS CHECKED

School/Work Name ____________________

Address ____________________

Phone # ____________________

Date In ____________

Date Out ____________

JOB TICKET

Customer Name ____________________

Customer Address ____________________

Customer Phone # ____________________

Vehicle/Equip.	Make & Model	License #/Motor #/Serial #	Speedometer

Condition reported by customer/service requested: ____________________

Services/repairs made: ____________________

	LABOR	

Customer Authorization

I, the undersigned, have reviewed the required service and parts estimates and authorize this maintenance to be performed with the understanding that I will be notified prior to the performance of any work that significantly exceeds those estimates in time or cost.

____________________ Date ____________

Technician ____________

Supervisor ____________

Objective 16

Job Sheet 4—Access Engine Parameters; Monitor or Change as Requested by Customer

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Directions are followed	______
• Safety procedures are followed	______
• Electronic equipment is used properly	______
• Service manual is used properly	______
• Parameters are correctly identified and changed	______
• Specifications are checked	______
• Job ticket is filled out properly	______
• Cleanup is adequate	______

Basic Skills

Reading Writing Science Critical Thinking Employability

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, Equipment, and Materials

- Technician's common hand tools
- Appropriate service manual, including explanation of diagnostic codes
- Job ticket or work order—one is included or use appropriate one provided at your facility
- Electronic diagnostic equipment—designed or adapted for vehicle
- Personal computer (PC) with appropriate software
- Appropriate electronic adapters
- Electronic fuel injection system to be worked on
- Others—as recommended by instructor and equipment service manual

Procedure

☐ 1. Locate and follow the appropriate procedure in the service manual.

☐ 2. Complete the accompanying job ticket with all pertinent information.

☐ 3. Turn ignition off.

☐ 4. Check terminals at all ECM connectors for damage, corrosion, and unseated pins or sockets.

☐ 5. Plug in the multi-pin wiring connectors/adapters for the diagnostic equipment and computer to be used.

☐ 6. Turn on diagnostic equipment and computer.

☐ 7. Turn on vehicle's ignition switch.

☐ 8. Go to computer main menu, and follow computer prompts to access engine parameters.

Examples: Maximum engine speed, torque curve, idle speeds, etc.

☐ 9. Change parameters as requested by customer (or instructor). Record on job ticket.

☐ 10. Return to main menu, and follow prompts to access engine performance information.

Example: Cylinder balances, pressures, mpg, etc.

☐ 11. Print out any information requested by customer (or instructor). Record on job ticket and attach copy of printout.

☐ 12. Disconnect diagnostic equipment and computer connection and reconnect appropriate electrical connectors, if necessary.

☐ 13. Check vehicle operation to verify any changes that were made.

☐ 14. Turn in job ticket when finished.

☐ 15. Clean work area and return tools and materials to proper storage.

Evaluator's Comments: ______________________________

____

____

PARTS LIST

QTY.	PARTS/MATERIALS	PRICE	
TOTAL PARTS/MATERIALS			

SPECIFICATIONS CHECKED

School/Work Name ______________________

Address ______________________

Phone # ______________________

Date In ______________

Date Out ______________

JOB TICKET

Customer Name ______________________

Customer Address ______________________

Customer Phone # ______________________

Vehicle/Equip.	Make & Model	License #/Motor #/Serial #	Speedometer

Condition reported by customer/service requested ______________________

____

Services/repairs made: ______________________

LABOR	

Customer Authorization

I, the undersigned, have reviewed the required service and parts estimates and authorize this maintenance to be performed with the understanding that I will be notified prior to the performance of any work that significantly exceeds those estimates in time or cost.

______________________ Date ______________

Technician ______________

Supervisor ______________

Job Sheet 4

Objective 17

Job Sheet 5—Remove, Inspect, and Rebuild or Replace a Fuel Transfer Pump

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Directions are followed	______
• Safety procedures are followed	______
• Service manual is used properly	______
• Parts are inspected accurately	______
• Specifications are checked	______
• Adjustments/replacements/repairs are made	______
• Job ticket is filled out properly	______
• Cleanup is adequate	______

Basic Skills

Reading Writing Critical Thinking Employability

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, Equipment, and Materials

- Technician's common hand tools
- Appropriate service manual, including explanation of diagnostic codes
- Job ticket or work order—one is included or use appropriate one provided at your facility
- Appropriate replacement parts—seals, gaskets, etc.
- Electronic fuel injection system to be worked on
- Others—as recommended by instructor and equipment service manual

Procedure

☐ 1. Locate and follow the appropriate procedure in the service manual.

☐ 2. Complete the accompanying job ticket with all pertinent information.

☐ 3. Remove fuel lines to fuel transfer pump.

☐ 4. Remove mounting bolts.

☐ 5. Remove transfer pump and mounting seals and gaskets.

☐ 6. Inspect pump for damage to seals, mounting components, and housing.

☐ 7. Inspect drive hub coupling for wear or damage. Replace as needed.

☐ 8. Rebuild fuel transfer pump as outlined in service manual.

☐ 9. Reinstall fuel transfer pump.

☐ 10. Reconnect fuel lines.

☐ 11. Bleed air from fuel system.

☐ 12. Start engine and check for correct operation. Check to make sure there are no leaks. Also check operating pressures to make sure they are correct.

☐ 13. Turn in job ticket when finished.

☐ 14. Clean work area and return tools and materials to proper storage.

Evaluator's Comments: ______________________________

____

____

PARTS LIST

QTY.	PARTS/MATERIALS	PRICE	
TOTAL PARTS/MATERIALS			

SPECIFICATIONS CHECKED

School/Work Name ____________________

Address ____________________

Phone # ____________________

Date In ____________

Date Out ____________

JOB TICKET

Customer Name ____________________

Customer Address ____________________

Customer Phone # ____________________

Vehicle/Equip.	Make & Model	License #/Motor #/Serial #	Speedometer

Condition reported by customer/service requested: ____________________

Services/repairs made: ____________________

LABOR	

Customer Authorization

I, the undersigned, have reviewed the required service and parts estimates and authorize this maintenance to be performed with the understanding that I will be notified prior to the performance of any work that significantly exceeds those estimates in time or cost.

____________________ Date ____________

Technician ____________

Supervisor ____________

Objective 18

Job Sheet 6—Remove, Inspect, Reinstall, and Adjust Electronic Unit Injectors; Determine Needed Repairs

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Directions are followed	______
• Safety procedures are followed	______
• Service manual is used properly	______
• Parts are inspected accurately	______
• Specifications are checked	______
• Adjustments/replacements/repairs are made	______
• Job ticket is filled out properly	______
• Cleanup is adequate	______

Basic Skills

Reading Writing Critical Thinking Employability

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, Equipment, and Materials

- Technician's common hand tools
- Appropriate service manual, including explanation of diagnostic codes
- Job ticket or work order—one is included or use appropriate one provided at your facility
- Eye protection
- Drain pan
- Pry bar
- Clean shop towels
- Clean solvent
- Ethylene glycol
- Electronic fuel injection system to be worked on
- Others—as recommended by instructor and equipment service manual

Procedure

☐ 1. Locate and follow the appropriate procedure in the service manual.

☐ 2. Complete the accompanying job ticket with all pertinent information.

☐ 3. Clean and remove rocker arm cover.

☐ 4. Drain cylinder head fuel gallery for a minimum of five minutes into a suitable drain pan.

Note: This is required to prevent fuel from entering the combustion chamber when the injector(s) is removed.

☐ 5. Loosen the injector wire terminal screws, and remove the terminal wires. DO NOT remove the screws from the injector. Turning the screws too far out will damage the threads in the injector solenoid housing.

☐ 6. Remove the two rocker shaft through-bolts, and lift the rocker shaft off the engine.

☐ 7. Remove injector hold down, and then remove the injector from its seat in the cylinder head using a pry bar under the injector body. Use care to prevent damage to the electronic unit injector.

☐ 8. Cover the injector hole in the cylinder head to keep out foreign material.

☐ 9. Clean injector tube bore and inspect for damage.

☐ 10. Clean the exterior of the injector with clean solvent. Dry with compressed air.

☐ 11. Inspect the injector and the fuel injector tubes at the injector seat. Determine needed repairs.

☐ 12. Install new injector o-rings. Make sure they are seated properly, and lubricate with clean ethylene glycol.

☐ 13. Insert injector into its injector tube bore. Align in bore and seat in injector tube.

☐ 14. Reinstall hold downs. Make sure they do not interfere with injector follower spring or valve springs.

☐ 15. Tighten hold down bolts to manufacturer's specifications.

☐ 16. Install electronic unit injector terminal wires as outlined in service manual. Tighten the screws to manufacturer's specifications.

☐ 17. Install the rocker arm shaft.

☐ 18. Adjust intake and exhaust valve clearances and injector height as outlined in the service manual.

☐ 19. Install the inlet and outlet fuel lines to the fittings at the rear of the cylinder head.

☐ 20. Install valve rocker cover, and continue with engine assembly.

☐ 21. Turn in job ticket when finished.

☐ 22. Clean work area and return tools and materials to proper storage.

Evaluator's Comments: ______________________________

____

____

Job Sheet 6

PARTS LIST

QTY.	PARTS/MATERIALS	PRICE	
TOTAL PARTS/MATERIALS			

SPECIFICATIONS CHECKED

School/Work Name ______________________

Address ______________________

Phone # ______________________

Date In ____________

Date Out ____________

JOB TICKET

Customer Name ______________________

Customer Address ______________________

Customer Phone # ______________________

Vehicle/Equip.	Make & Model	License #/Motor #/Serial #	Speedometer

Condition reported by customer/service requested: ______________________

Services/repairs made: ______________________

	LABOR	

Customer Authorization

I, the undersigned, have reviewed the required service and parts estimates and authorize this maintenance to be performed with the understanding that I will be notified prior to the performance of any work that significantly exceeds those estimates in time or cost.

______________________ Date ____________

Technician ____________

Supervisor ____________

Unit Contents

Student Components

Student Page

Objective Sheet 4C-3

Information Sheet 4C-5

Job Sheets

1—Check Vehicle for Presence and Operation of Emission Control Devices 4C-19
2—Check Vehicle for Fuel Type and Appropriate Application 4C-23
3—Test Vehicle for Excessive Exhaust Smoke 4C-27
4—Check Vehicle for Noise Abatement Devices 4C-31

975

Objective Sheet

Unit Objective

After completing this unit, the student should be able to describe exhaust emissions and discuss environmental issues affected by emissions. The student should also be able to check vehicles for emission control and noise abatement devices. The student should demonstrate these competencies by completing the job sheets and by scoring a minimum of 85 percent on the written test.

Specific Objectives

After completing this unit, the student should be able to:

1. Match terms related to emissions with their definitions.
2. Identify the chemical components involved in the diesel fuel combustion reaction.
3. Match exhaust emissions with their characteristics.
4. Distinguish between the types of smoke emissions.
5. Complete statements concerning environmental issues affected by emissions.
6. Complete statements concerning the federal Clean Air Act.
7. Match tests for emissions with their descriptions.
8. Describe efforts to improve emissions.
9. Match alternative/clean fuels with their descriptions.
10. List methods for reducing noise levels.
11. Check vehicle for presence and operation of emission control devices. (Job Sheet 1)
12. Check vehicle for fuel type and appropriate application. (Job Sheet 2)
13. Test vehicle for excessive exhaust smoke. (Job Sheet 3)
14. Check vehicle for noise abatement devices. (Job Sheet 4)

Information Sheet

Objective 1

Terms and definitions

a. **Abatement**—Reducing or eliminating environmental hazards

b. **Acid rain**—Atmospheric moisture falling to the ground as rain, snow, ice, or fog that has a pH of less than 5.6 (acidic)

Note: Normal pH of water is 6.5 to 8.5, with 7 being neutral.

c. **Air pollution episode**—Period of abnormally high concentrations of air pollutants

d. **Ambient air**—Any unconfined portion of the atmosphere; the outside air

e. **Atmosphere**—Mass of air surrounding the earth held by the force of gravity

f. **Carcinogen**—Substance that produces cancer

g. **Clean fuels**—Blends or substitutes for petroleum-based fuels

h. **Combustion**—Chemical process of burning that releases heat, light and chemical by-products

Note: Each time a fuel is burned in a combustion process, some type of pollutant is released into the air. The pollutant is greater when the combustion process is incomplete.

i. **Emission**—Pollutant discharged into the air

Note: Emissions commonly come from smokestacks, chimneys, and vehicle exhausts created through the combustion process. However, some chemical compounds (volatiles) also release emissions just by being exposed to air; these are called evaporative emissions.

j. **Emission standard**—Maximum amount of air-polluting discharge legally allowed from a single source (mobile or stationary)

k. **Environment**—Sum of all external conditions affecting the life, development, and survival of an organism

l. **Fluorocarbons (FCs)**—Any of a number of organic compounds analogous to hydrocarbons in which one or more hydrogen atoms are replaced by fluorine

Note: Fluorocarbons were once used in the United States as propellants for domestic aerosols; they are now found mainly in coolants and some industrial processes. FCs containing chlorine are called chlorofluorocarbons (CFCs).

m. **Fossil fuel**—Energy source derived from ancient organic (carbon-based) remains

Examples: Peat, coal, crude oil, natural gas, petroleum

n. **Fuel efficiency**—Proportion of useful energy to total energy released upon combustion of a fuel

o. **Hydrocarbons**—Organic compounds of hydrogen and carbon, such as those occurring in fossil fuels

p. **National ambient air quality standards (NAAQS)**—Level of pollutants in the outside air that cannot be exceeded during a specified time in a specified geographical area as established by EPA

q. **Noise**—Excessively loud or undesirable sound

r. **Non-attainment area**—Area that does not meet one or more of the NAAQS for the criteria pollutants designated in the Clean Air Act

s. **Particulate**—Fine liquid or solid particles such as dust, smoke, mist, fumes, or smog found in air or emissions

t. **Pollutant**—Any introduced gas, liquid, or solid that makes a resource unfit for a specific purpose

u. **Pollution**—Presence of matter or energy whose nature, location, or quantity produces undesirable environmental effects

v. **Smoke**—Particles suspended in the air after incomplete combustion

w. **Toxic**—Capable of causing death, disease, or birth defects if ingested or absorbed; hazardous even at low concentration

x. **Volatile**—Readily vaporized (evaporated)

y. **Volatile organic compound (VOC)**—Any organic compound that contributes to smog

Objective 2

Diesel fuel combustion reaction

Figure 1

$$\underbrace{C_xH_yS_z}_{\text{Diesel fuel}} + \underbrace{O_2 + N_2}_{\text{Air}} \rightarrow \underbrace{CO_2 + H_2O + N_2 + O_2}_{\text{Major exhaust components}} + \underbrace{NO_x + HC + CO + SO_x + C}_{\text{Minor exhaust components (trace amounts)}}$$

Note: The small letters x, y, and z mathematically stand for variable numbers—0, 1, 2, etc. This means, for example, NO_x may be NO_1 or NO_2.

Objective 3

Exhaust emissions and their characteristics

a. **Oxides of nitrogen (NO_x)**

- Collective name for compounds of nitrogen and oxygen formed at high temperatures such as during combustion
    - NO—Nitric oxide—Colorless gas
    - NO_2—Nitrogen dioxide—Yellowish, brown gas
    - N_2O—Nitrous oxide—Colorless gas that relieves pain (laughing gas)
- Reacts with hydrocarbons in the presence of sunlight to form ozone
- Combines with other chemicals to create acids that fall to earth as acid rain
- Can irritate the lungs, cause bronchitis and pneumonia, and lower resistance to respiratory infections
- Issue for diesel engines under high-load conditions

b. **Hydrocarbons (HC)**

- Collective name for over 100 different compounds made up of carbon (C) and hydrogen (H)
- Product of incomplete combustion of fuel
- Potential issue for diesel engines at low loads, during cold conditions, and while motoring
- Lube oil that gets past the piston rings and valve guides becomes hydrocarbon emissions.
- Reacts with oxides of nitrogen in the presence of sunlight to form ozone

c. **Ozone (O_3)**

- Form of molecular oxygen consisting of three oxygen atoms linked together
- Pungent, colorless gas
- Formed through complex chemical reactions between precursor emissions of volatile organic compounds (VOC) and nitrogen oxides in the presence of sunlight. Rate of reaction is related to temperature and intensity of sunlight.

- Evaporative emissions are a major source of hydrocarbon compounds that form ground-level ozone.
- Ozone is beneficial in the upper atmosphere by shielding the earth from the sun's harmful ultraviolet radiation. However ozone is harmful at ground level as an emission.
- Ozone is a major component of smog. It irritates eyes and respiratory system, damages lung tissue, aggravates respiratory disease, and increases susceptibility to respiratory infections.
- Ozone level is exceeded in nearly 100 U.S. cities.

d. **Carbon monoxide (CO)**

- Colorless, odorless gas
- Enters the bloodstream and reduces the delivery of oxygen to the body's organs and tissues
- Exposure to elevated CO levels is associated with impairment of visual perception, manual dexterity, learning ability, and performance of complex tasks
- Formed during the intermediate combustion stages of hydrocarbon fuels
- Though measured and regulated, it is usually not an issue for diesel engines. Diesels typically have low CO emissions due to their lean combustion process.

e. **Oxides of sulfur (SO_x)**

- Product of oxidation of the fuel-bound sulfur during the combustion process
- Reacts with water in the atmosphere and falls to earth as sulfuric acid (H_2SO_4), an acid rain component
- Method of control is to limit the sulfur content of the fuel.
- High concentrations affect breathing and may aggravate existing respiratory and cardiovascular disease.
- Produces foliar damage on trees and agricultural crops

f. **Particulate matter (PM)**

- Collective name for very small substances deposited on a filter as diluted exhaust is passed through it. Main constituents include carbon particles, heavy hydrocarbons from fuel and lube oil, sulfates, and ash.

950

- Carbon particles (soot) are formed when insufficient air or low combustion temperature prohibits complete combustion of the free carbon.
- In 1987, EPA changed from a Total Suspended Particulate standard to a PM-10 standard. PM-10 includes only those particles with aerodynamic diameter smaller than 10 micrometers.
- Fine particles penetrate to the deepest parts of the lung. They aggravate respiratory conditions, reduce lung function, increase susceptibility to infections, and cause structural changes in lung tissue.
- Diesel particulates are considered probable carcinogens by the International Agency for Research on Cancer (IARC).

g. **Carbon dioxide (CO_2)**

- One of the major constituents in the exhaust of diesel combustion
- However, diesel engines produce less CO_2 per unit of work compared to other engines that burn petroleum-based fuels.
- Although CO_2 is non-toxic, it is associated with global warming, a separate environmental issue.

Objective 4

Types of smoke emissions

a. **Black smoke**

- Made up of carbon particles that escape the combustion process which then block the passage of light through the exhaust
- Is typically emitted during accelerations and at high loads

b. **White smoke**

- Made up of particles of essentially colorless liquid (unburned hydrocarbons and water vapor) which reflect or refract light
- Is an issue under cold conditions at low loads

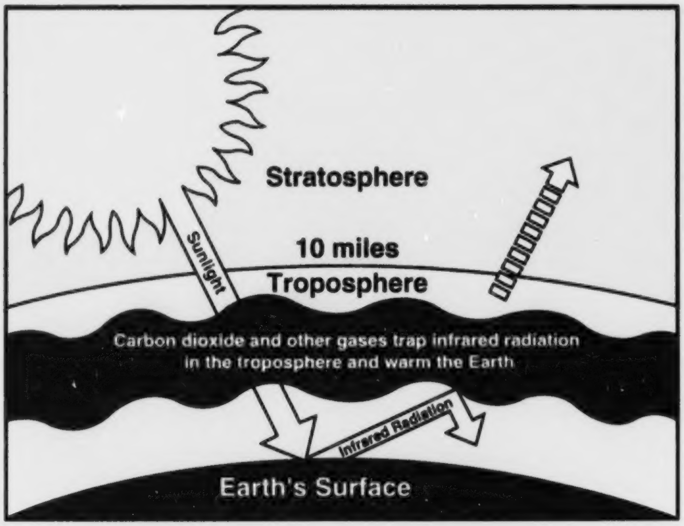
Objective 5

Environmental issues affected by emissions

a. Greenhouse gases and global warming

- A layer of carbon dioxide and other gases above the earth's surface acts like a glass on top of a greenhouse. Heat radiated from the sun passes through the carbon dioxide layer. Part of the heat is trapped by the carbon dioxide layer; the rest is radiated back to the atmosphere.

Figure 2—Greenhouse effect


Stratosphere
Sunlight
10 miles
Troposphere
Carbon dioxide and other gases trap infrared radiation in the troposphere and warm the Earth
Infrared Radiation
Earth's Surface

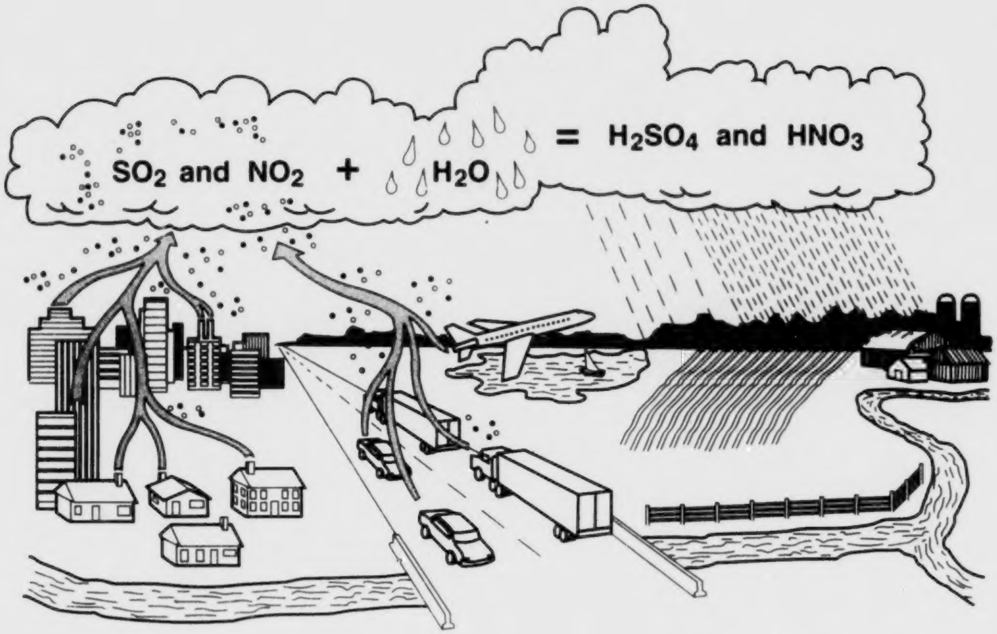
Courtesy of U.S. EPA

- Many scientists believe that an increase in the atmospheric concentration of carbon dioxide can eventually cause an increase in the earth's surface temperature—global warming.
- Others feel that as carbon dioxide levels increase, plant growth also increases, thereby holding the harmful "greenhouse effect" to a minimum.
- Burning fewer carbon products including fossil fuels, plants (especially forests), and animal wastes should result in less carbon dioxide production and reduced greenhouse effect.
- Use of clean fuels (non-petroleum) should also help slow the atmospheric buildup of carbon dioxide and other greenhouse gases.

b. **Acid rain**

- Occurs when oxides of sulfur and nitrogen combine with atmospheric moisture (water, ice, snow). Acid rain is formed.
  - Sulfur dioxide (SO_2) combines with water (H_2O) to produce sulfuric acid (H_2SO_4).
  - Nitrogen dioxide (NO_2) combines with water (H_2O) to produce nitric acid (HNO_3).
- Winds transport airborne acid particles hundreds of miles across state and national borders.

Figure 3—Acid rain


SO_2 and NO_2 + H_2O = H_2SO_4 and HNO_3

- Reduced emissions of sulfur and nitrogen oxides should help with acid rain problem.

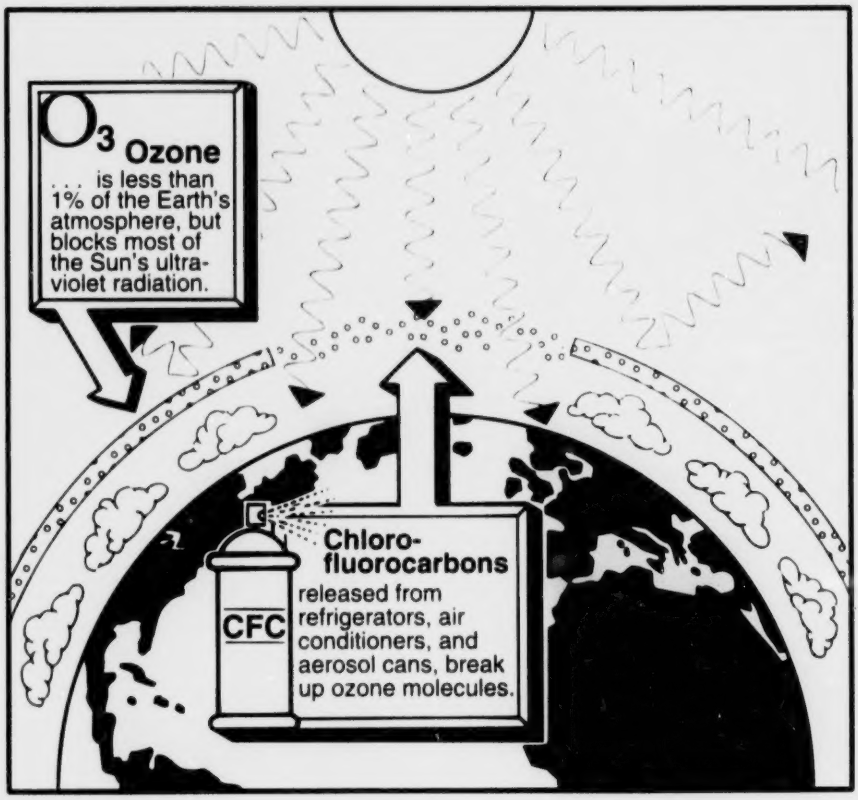
c. **Stratospheric ozone depletion**

- The ozone shield is a layer of ozone in the stratosphere 6 to 30 miles above the earth that protects all earth organisms from dangerous ultraviolet radiation from the sun.

  It is being depleted by certain chlorine and/or bromine compounds including chlorofluorocarbons (CFC), as well as nitrogen oxides from combustion of fossil fuels.

- Reduced nitrogen oxide emissions and current bans on CFCs by international treaty should help to preserve the ozone shield.

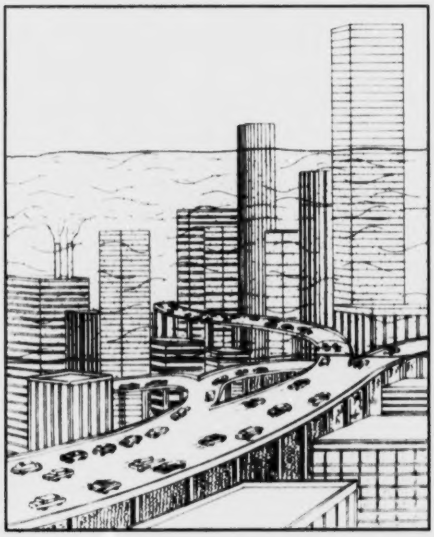
Figure 4—Ozone shield


O_3 Ozone
. . . is less than 1% of the Earth's atmosphere, but blocks most of the Sun's ultraviolet radiation.
CFC
Chlorofluorocarbons
released from refrigerators, air conditioners, and aerosol cans, break up ozone molecules.

d. **Smog**

- The word "smog" is formed by combining the words "smoke and fog." It permeates the air like a fog created by smoke and other air pollutants.
- Smog is formed by the action of sunlight on oxides of hydrogen, hydrocarbons, and ground level ozone, its major component.
- It is considered the most serious and persistent air quality problem in the U.S. today.

Figure 5—Smog



- Smog is a severe irritant responsible for choking, coughing, and stinging eyes. Numerous deaths are reported each year, especially among those with respiratory illnesses.
- It is a serious problem in most large urban areas. It can also be carried by winds and affect downwind rural areas.
- Smog is more severe in the following situations:
  - When accompanied by temperature inversions. This occurs when a layer of cool air is trapped by an upper layer of warm air. Inversions hold polluted air closer to the ground.
  - In stagnant air conditions where dilution by fresh air is minimized. This includes cities surrounded by large buildings or areas protected by mountains.
  - In sunny locations such as Florida, Texas, and Southern California. Sunlight is necessary for the photochemical reaction that creates smog.

Objective 6

Federal Clean Air Act

a. The Clean Air Act regulates air emissions from both stationary and mobile sources.

b. This Act was originally passed into law in 1970.

- Its original goal was to set and achieve NAAQS in every state by 1975.
- It gave primary responsibility for regulating pollution from power plants, factories, and other "stationary sources" to state and local governments.
- It gave the Environmental Protection Agency (EPA) primary responsibility for regulating "mobile sources," which includes cars, trucks, buses, and aircraft.

c. The Act was amended in 1977 primarily to set new goals (dates) for achieving attainment of NAAQS since many areas of the country had failed to meet the deadlines.

d. The 1990 amendments to the Clean Air Act were intended to meet unaddressed or insufficiently addressed problems such as acid rain, ground-level ozone, stratospheric ozone depletion, and air toxics.

- Regulations limiting the amount of sulfur in diesel fuel took effect in 1993. The sulfur level was reduced by 80 percent. Today's lower-sulfur diesel fuels are important in reducing emission of particulate matter and other air toxics.
- The 1990 Act set specific emission standards for hydrocarbons and for diesel particulate matter. Beginning in 1993, the diesel particulate standard for urban buses was reduced by 60 percent. If monitoring data show that buses in actual use are not meeting the standard, EPA must implement a "low-polluting fuels" program for new buses in large cities.
- The 1990 Act requires the EPA to consider emissions from off-highway vehicles as well as from highway vehicles. Nonroad engines were not previously regulated for pollution.
- Other provisions of the 1990 Act primarily affect cars and light-duty vehicles with the use of reformulated gasoline and new tailpipe standards.

Objective 7

Tests for emissions

a. **Inspection and maintenance tests (I/M)**—Used to identify faulty emission controls and ensure their repair; involves two tests

   - Tailpipe test of exhaust emissions
   - Check to ensure that critical emission control components are present and functional

b. **Onboard diagnostics (OBD) systems**—Use vehicle computers to monitor emission control and to alert drivers and technicians about emission problems

c. **Remote sensing tests**

   - Take a "snapshot" of a vehicle's emissions as it passes by a sensor located on the side of the road
   - Used as a supplemental test primarily to identify high-emitting ("super-dirty") vehicles
   - Measures hydrocarbons and carbon monoxide; cannot measure nitrogen oxides or evaporative emissions

d. **"High-tech" tests for new vehicles**

   - Involves sophisticated tests of vehicles being operated on a dynamometer through a driving cycle (includes acceleration and deceleration)
   - Measures exhaust emissions including hydrocarbon, carbon monoxide, and nitrogen oxide
   - Also measures evaporative emissions including hydrocarbons

Objective 8

Efforts to improve emissions

a. **What has recently been done**

   - Oil companies/refineries changed diesel fuel composition and reduced the sulfur level to reduce harmful emissions.
   - Vehicle manufacturers used new technology to improve performance of new vehicles.
     - They increased the use of electronic fuel injection to improve engine efficiency and thereby reduce by-products of incomplete combustion.
     - They redesigned vehicles to include computerized diagnostic systems that monitor optimal engine performance and that alert drivers and technicians about malfunctioning emission controls.

- They increased the use of more efficient catalytic converters to reduce hydrocarbons and particulates.

- Diesel technicians and end-users (drivers/owners) monitor and inspect vehicles to make sure that emission control devices are operating correctly as designed by the manufacturer.

  Note: Changes in fuel composition and vehicle design have greatly reduced air emissions in the last 25 years. New vehicles are designed to emit less than half of the air toxics of their 1970 counterparts. However, emissions are still a serious problem because of the two-fold increase in the number of vehicles on the road and the miles they travel in the same time frame.

b. **What else can be done**

- Switch to alternative, non-petroleum fuels to reduce air toxics. This will require a great investment by vehicle manufacturers in new engine designs/redesigns, as well as a new infrastructure involving convenient alternative fueling stations.
- Remove "super-dirty" vehicles from the road. A relatively small number of old, deteriorating, and poorly maintained vehicles are major contributors to ozone-forming hydrocarbon emissions.
- Continue to make improvements in vehicle performance in order to use less fuel, as well as inventing new devices that can capture emissions or reconfigure emissions to be less harmful.

Objective 9

Alternative/clean fuels

Note: Out of 190 million vehicles on the road today, fewer than half a million run on alternative fuels all or most of the time. However, fleet owners; federal, state, and local governments; transit agencies; and private industries are experimenting with alternative fuels to address air pollution problems. Their use helps to advance cutting-edge vehicle technology by providing on-the-road data.

a. **Alcohols**

- Methanol (made from natural gas, coal, or biomass) and ethanol (made from sugars, grains and soy) are high-octane liquid fuels.
- They drastically reduce the emission of hydrocarbons compared to present fuels.
- These alcohols are often used in combination with diesel fuel (such as soy-diesel) to reduce the emission level.

b. **Electricity**

- Battery-powered vehicles have the potential for zero tailpipe and evaporative hydrocarbon and nitrogen oxide emissions.

  - Electric vehicles are being tested for fleet vehicles where long driving range is not important and for transit buses in cities with serious emission problems.
  - Today's electric vehicle technology is limited, but new developments and increased demand may lead to more widespread use in the future.

c. **Natural gas**

  - Compressed natural gas (CNG) is currently being used for fleet vehicles where long driving range is not important.
  - Liquefied natural gas (LNG) must be stored at extremely low temperatures, but it can then be used for longer driving distances.
  - Natural gas is also being used on vehicles with diesel fuel as a backup and for firing.
  - Natural gas vehicles have drastically reduced emission rates of hydrocarbons compared to present fuels.

d. **Liquid petroleum gas (LPG—propane)**

  - This is a by-product of petroleum refining and natural gas production.
  - LPG/Propane vehicles emit considerably less ozone-forming hydrocarbons than do vehicles with conventional fuels.

Objective 10

Methods for reducing noise levels

a. Engine redesigns, especially turbocharging and serpentine blocks

b. Tire redesigns

c. Transmission redesigns

d. Sound proofing of engine compartments

e. Sound proofing of cab

f. Fairings

g. Mufflers

  - Standard mufflers use baffles to dampen noise.
  - Electronic mufflers change frequencies of sounds coming out so human ear cannot detect.

Objective 11

Job Sheet 1—Check Vehicle for Presence and Operation of Emission Control Devices

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Directions are followed	______
• Safety procedures are followed	______
• Service manual is used properly	______
• Parts are inspected accurately	______
• Specifications are checked	______
• Job ticket is filled out properly	______
• Cleanup is adequate	______

Basic Skills

Reading Writing Science Critical Thinking Employability

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, Equipment, and Materials

- Technician's common hand tools
- Appropriate service manual
- Job ticket or work order—one is included or use appropriate one provided at your facility
- Electronic diagnostic scan tool—designed or adapted for vehicle
- Appropriate electronic adapters
- Vehicle to be worked on
- Others—as recommended by instructor and equipment service manual

Procedure

☐ 1. Locate and follow the appropriate procedure in the service manual.

☐ 2. Complete the accompanying job ticket with all pertinent information.

☐ 3. Check vehicle to see what emission control devices are being used such as catalytic converters, electronic fuel injection, electronic sensors, electronic control module (ECM), and onboard computer diagnostics. Record information on job sheet.

☐ 4. Check for evidence of tampering. Note on job ticket and notify instructor if tampering evidence is found.

Note: There are federal penalties for tampering. It is illegal to disconnect, modify, or alter any required emission control devices.

☐ 5. If vehicle is equipped with onboard computer diagnostics, connect diagnostic scan tool, turn on, and read active codes.

☐ 6. Refer to manufacturer's electronic troubleshooting manuals for explanation of codes and possible causes of trouble. Record fault codes related to emission problems on the job ticket.

☐ 7. Check with instructor before replacing any components related to emission problems or other problems identified by scan tool.

☐ 8. Disconnect scan tool and reconnect appropriate electrical connectors.

☐ 9. Turn in job ticket when finished.

☐ 10. Clean work area and return tools and materials to proper storage.

Evaluator's Comments: ______________________________

____

____

PARTS LIST

QTY.	PARTS/MATERIALS	PRICE	
TOTAL PARTS/MATERIALS			

SPECIFICATIONS CHECKED

School/Work Name ______________________

Address ______________________

Phone # ______________________

Date In ____________

Date Out ____________

JOB TICKET

Customer Name ______________________

Customer Address ______________________

Customer Phone # ______________________

Vehicle/Equip.	Make & Model	License #/Motor #/Serial #	Speedometer

Condition reported by customer/service requested: ______________________

Services/repairs made: ______________________

	LABOR	

Customer Authorization

I, the undersigned, have reviewed the required service and parts estimates and authorize this maintenance to be performed with the understanding that I will be notified prior to the performance of any work that significantly exceeds those estimates in time or cost.

______________________ Date ____________

Technician ____________

Supervisor ____________

Job Sheet 1

Objective 12

Job Sheet 2—Check Vehicle for Fuel Type and Appropriate Application

Name ________________________ Attempt Number ________

Date ________________________ Overall Rating ________

Evaluation Criteria	Rating
• Directions are followed	______
• Safety procedures are followed	______
• Service manual is used properly	______
• Parts are inspected accurately	______
• Specifications are checked	______
• Job ticket is filled out properly	______
• Cleanup is adequate	______

Basic Skills

Reading Writing Critical Thinking Employability

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, Equipment, and Materials

- Technician's common hand tools
- Appropriate service manual
- Job ticket or work order—one is included or use appropriate one provided at your facility
- Container for collecting fuel sample
- Vehicle to be worked on
- Others—as recommended by instructor and equipment service manual

Procedure

☐ 1. Locate and follow the appropriate procedure in the service manual.

☐ 2. Complete the accompanying job ticket with all pertinent information.

☐ 3. Identify the type of fuel being used and record on job ticket. Also describe any alternative fuels or other modifications to the fuel system that you see.

☐ 4. If standard diesel fuel is being used, drain a sample from the fuel tank. Record its appearance on the job ticket, especially its color.

  ☐ a. Diesel fuel intended for highway use should be clear.

  ☐ b. Diesel fuel intended for off-highway use (agriculture) should be colored.

☐ 5. Turn in job ticket when finished.

☐ 6. Clean work area and return tools and materials to proper storage.

Evaluator's Comments: ______________________________

PARTS LIST

QTY.	PARTS/MATERIALS	PRICE	
TOTAL PARTS/MATERIALS			

SPECIFICATIONS CHECKED

School/Work Name ______________________

Address ______________________

Phone # ______________________

Date In ______________________

Date Out ______________________

JOB TICKET

Customer Name ______________________

Customer Address ______________________

Customer Phone # ______________________

Vehicle/Equip.	Make & Model	License #/Motor #/Serial #	Speedometer

Condition reported by customer/service requested: ______________________

Services/repairs made: ______________________

LABOR	

Customer Authorization

I, the undersigned, have reviewed the required service and parts estimates and authorize this maintenance to be performed with the understanding that I will be notified prior to the performance of any work that significantly exceeds those estimates in time or cost.

______________________ Date ______________________

Technician ______________________

Supervisor ______________________

Job Sheet 2

Objective 13

Job Sheet 3—Test Vehicle for Excessive Exhaust Smoke

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Directions are followed	______
• Safety procedures are followed	______
• Service manual is used properly	______
• Parts are inspected accurately	______
• Specifications are checked	______
• Adjustments/replacements/repairs are made	______
• Job ticket is filled out properly	______
• Cleanup is adequate	______

Basic Skills

Reading Writing Science Critical Thinking Employability

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, Equipment, and Materials

- Technician's common hand tools
- Appropriate service manual
- Job ticket or work order—one is included or use appropriate one provided at your facility
- Tailpipe emission probe
- Emission analyzer
- Opacity meter
- Vehicle to be worked on
- Others—as recommended by instructor and equipment service manual

Procedure

☐ 1. Locate and follow the appropriate procedure in the service manual.

☐ 2. Complete the accompanying job ticket with all pertinent information.

☐ 3. Park vehicle in properly ventilated test area.

☐ 4. Connect emission analyzer and opacity meter to vehicle's exhaust according to manufacturer's directions.

☐ 5. Start engine and allow to idle.

☐ 6. Record readings on analyzer and opacity meter.

☐ 7. Rev up engine and note any changes in exhaust readings.

☐ 8. Turn off engine and disconnect analyzer and meter.

☐ 9. Compare exhaust readings to permissible standards. Record all results on job ticket.

☐ 10. Discuss readings with instructor and determine what repairs are required for excessive emissions or smoke.

☐ 11. Turn in job ticket when finished.

☐ 12. Clean work area and return tools and materials to proper storage.

Evaluator's Comments: ______________________________

____

____

PARTS LIST

QTY.	PARTS/MATERIALS	PRICE
	TOTAL PARTS/MATERIALS	

SPECIFICATIONS CHECKED

School/Work Name __________
Address __________
Phone # __________

Date In __________
Date Out __________

JOB TICKET

Customer Name __________
Customer Address __________
Customer Phone # __________

Vehicle/Equip.	Make & Model	License #/Motor #/Serial #	Speedometer

Condition reported by customer/service requested: __________

Services/repairs made: __________

LABOR

Customer Authorization

I, the undersigned, have reviewed the required service and parts estimates and authorize this maintenance to be performed with the understanding that I will be notified prior to the performance of any work that significantly exceeds those estimates in time or cost.

__________ Date __________

Technician __________
Supervisor __________

Job Sheet 3

Objective 14

Job Sheet 4—Check Vehicle for Noise Abatement Devices

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Directions are followed	
• Safety procedures are followed	
• Service manual is used properly	
• Parts are inspected accurately	
• Specifications are checked	
• Job ticket is filled out properly	
• Cleanup is adequate	

Basic Skills

Reading Writing Critical Thinking Employability

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, Equipment, and Materials

- Technician's common hand tools
- Appropriate service manual
- Job ticket or work order—one is included or use appropriate one provided at your facility
- Vehicle to be worked on
- Others—as recommended by instructor and equipment service manual

Procedure

☐ 1. Locate and follow the appropriate procedure in the service manual.

☐ 2. Complete the accompanying job ticket with all pertinent information.

☐ 3. Check vehicle for noise abatement devices in and around the engine compartment. Record information on job ticket.

☐ 4. Check vehicle for noise abatement devices in and around the cab compartment. Record information on job ticket.

☐ 5. Turn in job ticket when finished.

☐ 6. Clean work area and return tools and materials to proper storage.

Evaluator's Comments: ______________________________

PARTS LIST

QTY.	PARTS/MATERIALS	PRICE	
TOTAL PARTS/MATERIALS			

SPECIFICATIONS CHECKED

School/Work Name ______________________
Address ______________________
Phone # ______________________

Date In ____________
Date Out ____________

JOB TICKET

Customer Name ______________________
Customer Address ______________________
Customer Phone # ______________________

Vehicle/Equip.	Make & Model	License #/Motor #/Serial #	Speedometer

Condition reported by customer/service requested: ______________________

____

Services/repairs made: ______________________

LABOR	

Customer Authorization

I, the undersigned, have reviewed the required service and parts estimates and authorize this maintenance to be performed with the understanding that I will be notified prior to the performance of any work that significantly exceeds those estimates in time or cost.

______________________ Date ____________

Technician ____________
Supervisor ____________

Unit Contents

Student Components

Student Page

Objective Sheet 1D-3

Information Sheet 1D-5

Student Supplement

1—SAE Codes 1D-13

Assignment Sheets

1—Conduct an Operator Survey for Engine Diagnosis 1D-25
2—Interpret SAE Code Identifiers 1D-29

Job Sheets

1—Check Air Intake System for Restrictions 1D-31
2—Check Exhaust Back Pressure 1D-35
3—Check Crankcase Pressure 1D-39
4—Check Oil Pressure 1D-43
5—Load Test an Engine with a Dynamometer 1D-47
6—Locate a Misfiring Cylinder 1D-51
7—Locate an Active Fault Code 1D-55

1006

Objective Sheet

Unit Objective

After completing this unit, the student should be able to evaluate engine performance using established test procedures and tools and evaluate the results. Additionally, the student will conduct an operator survey to gather information to aid engine diagnosis. The student should demonstrate these competencies by completing the assignment sheets and job sheets and by scoring a minimum of 85 percent on the written test.

Specific Objectives

After completing this unit, the student should be able to:

1. Match terms related to general engine diagnosis with their definitions.
2. Arrange in order the steps used in evaluating engine performance.
3. List the benefits of the operator questionnaire.
4. Describe the major checkpoints in a visual inspection for various engine systems.
5. Describe major performance checkpoints for various engine systems.
6. Discuss performance tests made with the engine on a dynamometer.
7. Distinguish among the functions of engine computer fault detection.
8. Match methods of engine computer fault code storage with their descriptions.
9. Match methods of engine computer fault code retrieval with their descriptions.
10. Complete statements concerning SAE code identifiers.
11. Conduct an operator survey for engine diagnosis. (Assignment Sheet 1)
12. Interpret SAE code identifiers. (Assignment Sheet 2)
13. Check air intake system for restrictions. (Job Sheet 1)
14. Check exhaust back pressure. (Job Sheet 2)
15. Check crankcase pressure. (Job Sheet 3)
16. Check oil pressure. (Job Sheet 4)
17. Load test an engine with a dynamometer. (Job Sheet 5)
18. Locate a misfiring cylinder. (Job Sheet 6)
19. Locate an active fault code. (Job Sheet 7)

Information Sheet

Objective 1

Terms and definitions

a. **Aeration**—Foaming caused by air mixing with a liquid, such as oil or fuel

b. **Dynamometer**—Device that measures the engine power output by applying a load to the engine

c. **Diagnostic data link (DDL)**—Allows shop test equipment to "plug into" the ECM

d. **Electronic control module (ECM)**—Computer that processes information from engine sensors and controls the fuel injector solenoid

e. **Electronic unit injector (EUI)**—Uses an ECM-controlled, injector-mounted electric solenoid to control amount and timing of injected fuel

f. **Infrared thermometer**—Instrument that measures temperatures up to 500°F

g. **Magnahelic gauge**—Sensitive instrument that measures small differences in pressure or vacuum

h. **Manometer**—Device that measures positive or negative pressure (vacuum)

Note: A manometer may use a column of water or mercury (Hg) for making measurements. Mercury manometers are typically used in high heat applications such as exhaust manifolds.

i. **Personality module**—Contains customer-specified information concerning engine performance

j. **Pyrometer**—Device that measures high exhaust temperatures (usually over 300°F)

k. **Snapshot**—ECM recordings at time and operating parameters when a fault occurs

l. **Symptom**—Indication of a mechanical or electrical/electronic problem

m. **Tachometer**—Device that measures engine speed

n. **Troubleshooting**—Process using test instruments to locate and diagnose the cause of failure

Information Sheet

Objective 2

Steps used in evaluating engine performance

a. Survey the operator.

Note: This is the best source of information.

b. Visually inspect the vehicle.

- Fluid levels
- Fluid condition
- Component condition

c. Test the performance of the vehicle.

- Without a dynamometer
- With a dynamometer

d. Use computer diagnostic abilities to test the vehicle.

- On-board system self-tests
- Hand-held testers

e. Locate symptom(s) in manufacturer's troubleshooting chart.

- With a symptom
- With a trouble code

Objective 3

Benefits of the operator questionnaire

a. Provides direct communication between operator and technician

b. Assists technician in troubleshooting, especially when no fault codes are available

c. Eliminates wasted technician time by providing specific information

Objective 4

Major checkpoints in a visual inspection

a. Cooling system

- Level
- Condition (supplemental coolant additive level)
- Maintenance history
- Leaks (radiator/hoses/pump)

b. Lubricating system
  - Level
  - Condition (sample)
  - Maintenance history
  - Leaks

c. Fuel system
  - Fuel level
  - Condition (sample)
  - Leaks
  - Hoses/clamps
  - Wiring harnesses/connectors

d. Electrical system
  - Belts
  - Connections (clean and tight/corroded)
  - Wiring harnesses/connectors
  - Battery electrolyte level
  - Charging system

e. Air intake system
  - Filter(s)
  - Ducting/hoses
  - Clamps/joints
  - Turbocharger

f. Exhaust system
  - Pipes
  - Connections
  - Muffler
  - Turbocharger

Information Sheet

Objective 5

Major performance checkpoints

a. Cooling system

- Pressure test radiator/cap
- Check for bubbles/flow at operating temperatures

b. Lubrication system

- Pressure check with shop gauge
- Temperature check (sump)

c. Fuel system

- Pressure check
- Flow (amount in a given time)
- Aeration

d. Electrical system

- Voltage
- Current

e. Air intake system

- Restriction level (vacuum)
- Pressure test intercooler core

f. Exhaust system

- Restriction (back pressure)
- Turbocharger noise

Objective 6

Performance tests made with the engine on a dynamometer

a. Engine power output

- Horsepower
- Torque

b. Exhaust smoke analysis

- Blue—Excess lubrication oil in the combustion chamber

- Black—Incomplete combustion of fuel
- White—Non-combustion of fuel

c. Fuel consumption

d. Crankcase blow-by

e. Air intake system

- Restriction
- Boost pressure

f. Exhaust system

- Back pressure
- Temperature

g. Lubrication system

- Pressure
- Temperature

Objective 7

Functions of engine computer fault detection

a. **Sensing abnormal operation**

- ECM detects abnormal input from sensors.
- ECM determines extent of variation.
- If engine-threatening, ECM limits engine speed and power output.

b. **Communicating with driver**

- Warning light
- Warning buzzer (optional)
- Power loss as ECM begins to derate/rampdown

c. **Communicating with technician**

- Fault code stored in memory
- Snapshot data

Objective 8

Engine computer fault code storage

a. **Inactive fault code**

- "Check Engine" light illuminates while problem exists.
- Fault code is stored in memory.
- Fault code is erased by computer command.

b. **Active fault code**

- "Check Engine" light comes on and stays on.
- Fault code is stored in memory.
- Fault code is erased by computer command.

c. **Snapshot data**

- Fault code is stored in memory.
- ECM records the time (in engine hours).
- ECM records engine operating conditions for a short-time before and after the fault occurred.

Objective 9

Engine computer fault code retrieval

a. **Hand-held communication tool**

- Connects to DDL
- Shows any fault stored in memory
- Initiates diagnostic sequence for ECM to check all electronic components
- Allows technician to see sensor output and actuator response

b. **Personal computer (PC) with a translator device**

- Translator connects to DDL; PC connects to translator.
- Shows fault codes
- Shows snapshot parameters on screen
- Allows technician to reprogram PROM (or EEPROM) with new parameters (some systems).

c. **"Check Engine" light**

- System activation (refer to OEM troubleshooting manual)
  - — Engine off, key on
  - — OEM-authorized jumper wires or test leads installed in DDL (some systems)
  - — Pressing a diagnostic switch (some systems)
- Lamp flashes are translated as digits for fault codes.

  Examples: Code 25 = 2 flashes, pause, 5 flashes

  Code 47 = 4 flashes, pause, 7 flashes
- Allows technician access to fault codes with no test equipment

Objective 10

SAE code identifiers

a. Each fault code uses three, three-digit number groups to describe the problem.

Example: 128 s110 04

b. First three-digit number group

- Message Identifier (MID)
- Identifies which microprocessor is broadcasting the code

c. Second three-digit number group (PID or SID)

- Parameter Identifier (PID)—Gives a numerical value; either degrees, volts, or psi
- Subsystem Identifier (SID)—Identifies the part that is malfunctioning

d. Third three-digit number group

- Fault Mode Identifier (FMI)
- Identifies what is wrong with the sensor signal
- Indicates whether the problem relates to current flow or voltage

Student Supplement 1—SAE Codes

Table 1—Message Identifiers (MIDs)		
MID	**Description**	**Text Message**
128	Engine #1	ENGINE
136	Anti-Lock Brakes (ABS)	TRCTR BRK
140	Instrumentation Control Unit, Left	INSTRCLST
142	Instrumentation Control Unit, Right	INSTRCLST
172	ServiceLink	DIAGNOSTC
179	Data Logging Unit	LOG CMPTR
182	Off-Board Programming Station	VEPS
190	Air Conditioning Protection Unit	ACPU

Table 2—Parameter Identifiers (PIDs)		
PID	**Description**	**Text Message**
51	Throttle Position	THROTTLE POS
52	Engine Intercooler Temperature	INTERCLR TEMP
53	Transmission Synchronizer Clutch Value	SYNCRO CLUTCH
54	Transmission Synchronizer Brake Value	SYNCRO BRAKE
55	Shift Finger Positional Status	SHFT FNGR POS
56	Transmission Range Switch Status	RANGE SWITCH
57	Transmission Actuator Status #2	ACTTRSTATUS#2
58	Shift Finger Actuator Status	SHFT FNGR ACT
59	Shift Finger Gear Position	SHFT FNGR GEAR
60	Shift Finger Rail Position	SHFT FNGR RAIL
61	Parking Brake Actuator Status	PRKBRKACTUATOR
62	Retarder Inhibit Status	RETARDRINHIBIT
63	Transmission Actuator Status #1	ACT STATUS #1
64	Direction Switch Status	DIRCTNSWCHSTAT
65	Service Brake Switch Status	SVCBRK SW STAT

Table 2—Parameter Identifiers (PIDs)		
PID	**Description**	**Text Message**
66	Vehicle Enabling Component Status	VEHENABLCMPTST
67	Shift Request Switch Status	SHFT RQST SWCH
68	Torque Limiting Factor	TRQ LIMIT FCTR
69	Two-Speed Axle Switch Status	2SPEEDAXLSWTCH
70	Parking Brake Switch	PARKBRK SWITCH
71	Idle Shutdown Timer Status	IDLEHSHUTDWNTMR
72	Blower Bypass Value Position	BLOWRBYPASSPOS
73	Auxiliary Water Pump Pressure	AUXWATRPMPPRSS
74	Maximum Road Speed Limit	MAXROADSPEED
75	Steering Axle Temperature	STRNGAXLTEMP
76	Axle Lift Air Pressure	AXLLIFTAIRPRES
77	Forward Rear Drive Axle Temperature	FWDRRDRVAXLTMP
78	Rear Rear Drive Axle Temperature	RRRRDRVAXLTEMP
79	Road Surface Temperature	ROAD SRFC TEMP
80	Washer Fluid Level	WASHRFLUIDLEVEL
81	Particulate Trap Inlet Pressure	PARTTRAPINLPRS
82	Air Start Pressure	AIRSTARTPRESS
83	Road Speed Limit Status	ROADSPDLIMITST
84	Road Speed	ROAD SPEED
85	Cruise Control Status	CRUISECNTRLST
86	Cruise Control Set Speed	CRUISE SET
87	Cruise Control High—Set Limit Speed	CRUISE HI SET
88	Cruise Control Low—Set Limit Speed	CRUISE LO SET
89	Power Takeoff Status	PTO STATUS
90	PTO Oil Temperature	PTO OIL TEMP
91	Percent Accelerator Pedal Position	ACCEL PDL POS%
92	Percent Engine Load	ENG LOAD %
93	Output Torque	OUTPUT TORQUE
94	Fuel Delivery Pressure	FUEL DLVR PRSS
95	Fuel Filter Differential Pressure	FUEL FILTER

Table 2—Parameter Identifiers (PIDs)		
PID	**Description**	**Text Message**
96	Fuel Level	FUEL LEVEL
97	Water in Fuel Indicator	WATER IN FUEL
98	Engine Oil Level	OIL LEVEL
99	Engine Oil Filter Differential Pressure	OIL FLTR PRES
100	Engine Oil Pressure	OIL PRESSURE
101	Crankcase Pressure	CRANKCASE PRES
102	Boost Pressure	BOOST PRESSR
103	Turbo Speed	TURBO SPEED
104	Turbo Oil Pressure	TURBO OIL PRES
105	Intake Manifold Temperature	INTKMNFLDTEMP
106	Air Inlet Pressure	AIR INLET PRSS
107	Air Filter Differential Pressure	AIR FILTER
108	Barometric Pressure	BAROM PRESSURE
109	Coolant Pressure	COOLNT PRESSR
110	Engine Coolant Temperature	ENGCOOLANTTEMP
111	Coolant Level	COOLANT LEVEL
112	Coolant Filter Differential Pressure	CLNTFLTRDIFPRS
113	Governor Droop	GOVERNOR DROOP
114	Net Battery Current	NET BATT CURR
115	Alternator Current	ALTERNATORAMPS
116	Brake Application Pressure	BRKAPPL PRESS
117	Brake Primary Pressure	BRK PRIM PRESS
118	Brake Secondary Pressure	BRK SEC PRESSR
119	Hydraulic Retarder Pressure	HYD RTDR PRESS
120	Hydraulic Retarder Oil Temperature	HYDRRTDROILTMP
121	Engine Retarder Status	ENGRTDRSTATUS
122	Engine Retarder Percent	ENG RETARDER %
123	Clutch Pressure	CLUTCH PRESSR
124	Transmission Oil Level	OIL LEVEL
125	Transmission Oil Level High/Low	TRANSOIL HI/LO

Table 2—Parameter Identifiers (PIDs)		
PID	**Description**	**Text Message**
126	Transmission Filter Differential Pressure	FILTERPRESSUR
127	Transmission Oil Pressure	OIL PRESSURE
154	Auxiliary Input and Output Status #2	AUX INP/OUTP #2
155	Auxiliary Input and Output Status #1	AUX IN/OUT #1
156	Injector Timing Rail Pressure	INJ TMG RLPRS
157	Injector Metering Rail Pressure	INJ METR RLPRS
158	Battery Potential (voltage)—Switched	BATTVLTGSWTCHD
159	Gas Supply Pressure	GAS SUPLY PRS
160	Main Shaft Speed	MAINSHAFTSPEED
161	Input Shaft Speed	INPUTSHAFT SPD
162	Transmission Range Selected	RANGE SELECTED
163	Transmission Range Attained	RANGE ATTAINED
164	Injection Control Pressure	INJ CTRL PRESR
165	Compass Bearing	COMPASSBEARING
166	Rated Engine Power	RATED ENG PWR
167	Alternator Potential (voltage)	VOLTS (ALT)
168	Battery Potential (voltage)	VOLTS (BATT)
169	Cargo Ambient Temperature	CARGOAMBTEMP
170	Cab Interior Temperature	CAB INT TEMP
171	Ambient Air Temperature	AMB AIR TEMP
172	Air Inlet Temperature	AIR INLET TEMP
173	Exhaust Gas Temperature	EXH GAS TEMP
174	Fuel Temperature	FUEL TEMP
175	Engine Oil Temperature	ENG OIL TEMP
176	Turbo Oil Temperature	TURBO OIL TEMP
177	Transmission Oil Temperature	TRAN OIL TEMP
178	Front Axle Weight	FRONT AXLE WT
179	Rear Axle Weight	REAR AXLE WT
180	Trailer Weight	TRAILER WEIGHT
181	Cargo Weight	CARGO WEIGHT

Table 2—Parameter Identifiers (PIDs)		
PID	**Description**	**Text Message**
182	Trip Fuel	TRIP FUEL
183	Fuel Rate	FUEL RATE
184	Instantaneous Fuel Economy	INST FUEL ECON
185	Average Fuel Economy	AVG FUEL ECON
186	Power Takeoff Speed	PTO SPEED
187	Power Takeoff Set Speed	PTO SET SPEED
188	Idle Engine Speed	IDLE ENG SPEED
189	Rated Engine Speed	RATED ENG SPD
190	Engine Speed	ENGINE SPEED
191	Transmission Output Shaft Speed	TRAN OUT SPEED
232	DGPS Differential Correction	DGPS DIF CRCTN
233	Power Unit Number	POWER UNIT #
234	Software Identification	SOFTWARE ID
235	Total Idle Hours	TOTL IDLE HRS
236	Total Idle Fuel Used	TOTL IDLE FUEL
237	Vehicle Identification Number	VIN
238	Velocity Vector	VELOCITYVECTOR
239	Vehicle Position	VEHICLE POS
240	Change Reference Number	CHG REF #
241	Tire Pressure	TIRE PRESSURE
242	Tire Temperature	TIRE TEMP
243	Component Identification	COMPONENT ID
244	Trip Distance	TRIP DISTANCE
245	Total Vehicle Distance	TOTAL VEH DIST
246	Total Vehicle Hours	TOTAL VEH HRS
247	Total Engine Hours	TOTAL ENG HRS
248	Total PTO Hours	TOTAL PTO HRS
249	Total Engine Revolutions	TOTAL ENG REVS
250	Total Fuel Used	TOTAL FUELUSED
251	Clock	CLOCK

Table 2—Parameter Identifiers (PIDs)		
PID	**Description**	**Text Message**
252	Date	DATE
253	Elapsed Time	ELAPSED TIME

Table 3—MID 128 Engine Sub-System Identifiers (SIDs)		
SID	**Description**	**Text Message**
1	Injector Cylinder #1	CYL #1 INJECTR
2	Injector Cylinder #2	CYL #2 INJECTR
3	Injector Cylinder #3	CYL #3 INJECTR
4	Injector Cylinder #4	CYL #4 INJECTR
5	Injector Cylinder #5	CYL #5 INJECTR
6	Injector Cylinder #6	CYL #6 INJECTR
7	Injector Cylinder #7	CYL #7 INJECTR
8	Injector Cylinder #8	CYL #8 INJECTR
9	Injector Cylinder #9	CYL #9 INJECTR
10	Injector Cylinder #10	CYL 10 INJECTR
11	Injector Cylinder #11	CYL 11 INJECTR
12	Injector Cylinder #12	CYL 12 INJECTR
13	Injector Cylinder #13	CYL 13 INJECTR
14	Injector Cylinder #14	CYL 14 INJECTR
15	Injector Cylinder #15	CYL 15 INJECTR
16	Injector Cylinder #16	CYL 16 INJECTR
17	Fuel Shutoff Valve	FUEL SHUTOFF
18	Fuel Control Valve	FUEL CONTROL
19	Throttle Bypass Valve	THROTTLE BYPAS
20	Timing Actuator	TIMINGACTUATOR
21	Engine Position Sensor	ENG POS SENSOR
22	Timing Sensor	TIMING SENSOR
23	Rack Actuator	RACK ACTUATOR

Table 3—MID 128 Engine Sub-System Identifiers (SIDs)

SID	Description	Text Message
24	Rack Position Sensor	RACKPOS SENSOR
25	External Engine Protection Input	EXT ENG PROTCT
26	Auxiliary Output Device Driver #1	AUXOUTDRIVER1
27	Variable Geometry Turbocharger Actuator #1	TURBO ACTUATR1
28	Variable Geometry Turbocharger Actuator #2	TURBO ACTUATR2
29	External Fuel Command Input	EXT FUEL INPUT
30	External Speed Command Input	EXT SPEEDINPUT
31	Tachometer Signal Output	TACHSIGNLOUTPT
32	Wastegate Output Device Driver	WASTEGATEDRVR
33	Fan Clutch Output Device Driver	FANCLTCH DRV
34	Exhaust Back Pressure Sensor	EXH PRESSENSOR
35	Exhaust Back Pressure Regulator Solenoid	EXH PRES SOL
36	Glow Plug Lamp	GLOWPLUGLAMP
37	Electronic Drive Unit Power Relay	DRV UNITPWRRLY
38	Glow Plug Relay	GLOWPLUGRELAY
39	Engine Starter Motor Relay	STARTER RELAY
40	Auxiliary Output Device Driver #2	AUXOUT DRIVER2
41	ECM 8 Volts DC Supply	ECM 8VDC SUPLY
42	Injection Control Pressure Regulator	INJ PRES REG
43	Autoshift High Gear Actuator	AUTOSHFTHI GR
44	Autoshift Low Gear Actuator	AUTOSHFTLO GR
45	Autoshift Neutral Gear Actuator	AUTOSHFTNTL GR
46	Autoshift Common Low Side (Return)	AUTOSHFTCOMLO
47	Injector Cylinder #17	CYL 17 INJECTR
48	Injector Cylinder #18	CYL 18 INJECTR
49	Injector Cylinder #19	CYL 19 INJECTR
50	Injector Cylinder #20	CYL 20 INJECTR
51	Auxiliary Output Device Driver #3	AUXOUT DRIVER3
52	Auxiliary Output Device Driver #4	AUXOUT DRIVER4
53	Auxiliary Output Device Driver #5	AUXOUT DRIVER5

Table 3—MID 128 Engine Sub-System Identifiers (SIDs)

SID	Description	Text Message
54	Auxiliary Output Device Driver #6	AUXOUT DRIVER6
55	Auxiliary Output Device Driver #7	AUXOUT DRIVER7
56	Auxiliary Output Device Driver #8	AUXOUT DRIVER8
57	Auxiliary PWN Driver #1	AUX PWM DRVR 1
58	Auxiliary PWN Driver #2	AUX PWM DRVR 2
59	Auxiliary PWN Driver #3	AUX PWM DRVR 3
60	Auxiliary PWN Driver #4	AUX PWM DRVR 4
61	Variable Swirl System Valve	VAR SWIRL VALV
62	Prestroke Sensor	PRESTROKE SNSR
63	Prestroke Actuator	PRESTROKE ACTR
64	Engine Speed Sensor #2	SPEED SENSOR2
65	Heated Oxygen Sensor	OXYGEN SENSOR
66	Ignition Control Mode Signal	IG MODE SIGNAL
67	Ignition Control Timing Signal	IG TIME SIGNAL
68	Secondary Turbo Inlet Pressure	TURBO PRSSRE 2
69	ACOC (Aftercooler/Oil Cooler) Coolant Temp	ACOC COOL TEMP
70	Inlet Air Heater Driver #1	—
71	Inlet Air Heater Driver #2	—
72	Injector Cylinder #21	CYL 21 INJECTR
73	Injector Cylinder #22	CYL 22 INJECTR
74	Injector Cylinder #23	CYL 23 INJECTR
75	Injector Cylinder #24	CYL 24 INJECTR
76	Knock Sensor	KNOCK SENSOR
77	Gas Metering Valve	GASMETER VALVE

Table 4—MID 136 ABS Sub-System Identifiers (SIDs)		
SID	**Description**	**Text Message**
1	Wheel Sensor ABS Axle 1 Left	WH SNSR AXL 1L
2	Wheel Sensor ABS Axle 1 Right	WH SNSR AXL 1R
3	Wheel Sensor ABS Axle 2 Left	WH SNSR AXL 2L
4	Wheel Sensor ABS Axle 2 Right	WH SNSR AXL 2R
5	Wheel Sensor ABS Axle 3 Left	WH SNSR AXL 3L
6	Wheel Sensor ABS Axle 3 Right	WH SNSR AXL 3R
7	Pressure Modulation Valve ABS Axle 1 Left	PRSMOD VLV A1L
8	Pressure Modulation Valve ABS Axle 1 Right	PRSMOD VLV A1R
9	Pressure Modulation Valve ABS Axle 2 Left	PRSMOD VLV A2L
10	Pressure Modulation Valve ABS Axle 2 Right	PRSMOD VLV A2R
11	Pressure Modulation Valve ABS Axle 3 Left	PRSMOD VLV A3L
12	Pressure Modulation Valve ABS Axle 3 Right	PRSMOD VLV A3R
13	Retarder Control Relay	RTDR CNTRL RLY
14	Relay Diagonal 1	RLAY DIAGONAL1
15	Relay Diagonal 2	RLAY DIAGONAL 2
16	Mode Switch ABS	ABS MODE SWTCH
17	Mode Switch ASR	ASR MODE SWTCH
18	DIF 1–ASR Valve	ASR DIF1 VALVE
19	DIF 2–ASR Valve	ASR DIF2 VALVE
20	Pneumatic Engine Control	PNEU ENG CNTRL
21	Electronic Engine Control (Servomotor)	ELEC ENG CNTRL
22	Speed Signal Input	SPN SNGL INPUT
23	Warming Light Bulb	WARNLIGHT BULB
24	ASR Light Bulb	ASR LIGHTBULB
25	Wheel Sensor, ABS Axle 1 Average	SENSOR AX1 AVG
26	Wheel Sensor, ABS Axle 2 Average	SENSOR AX2 AVG
27	Wheel Sensor, ABS Axle 3 Average	SENSOR AX3 AVG
28	Pressure Modulator, Drive Axle Relay Valve	PRSSRMODDRVAXL
29	Pressure Transducer, Drive Axle Relay Valve	PRSSRXDCDRVAXL
30	Master Control Relay	MASTER RELAY

Table 4—MIC 136 ABS Sub-System Identifiers (SIDs)

SID	Description	Text Message
31	Trailer Brake Slack Out of Adjust Frwrd Axle Left	BRAKE ADJUST
32	Trailer Brake Slack Out of Adjust Frwrd Axle Right	BRAKE ADJUST
33	Trailer Brake Slack Out of Adjust Rear Axle Left	BRAKE ADJUST
34	Trailer Brake Slack Out of Adjust Rear Axle Right	BRAKE ADJUST
35	Tractor Brake Slack Out of Adjust Axle 1 Left	BRAKE ADJUST
36	Tractor Brake Slack Out of Adjust Axle 1 Right	BRAKE ADJUST
37	Tractor Brake Slack Out of Adjust Axle 2 Left	BRAKE ADJUST
38	Tractor Brake Slack Out of Adjust Axle 2 Right	BRAKE ADJUST
39	Tractor Brake Slack Out of Adjust Axle 3 Left	BRAKE ADJUST
40	Tractor Brake Slack Out of Adjust Axle 3 Right	BRAKE ADJUST

Table 5—MIC 190 APADS Sub-System Identifiers (SIDs)

SID	Description	Text Message
1	Refrigerant Charge	REFRGNT CHRG
2	Refrigerant Moisture Level	REFRIG MOISTR
3	Non-Condensable Gas in Refrigerant	GAS IN REFRIGN
4	Refrigerant Flow Control Solenoid	RFRG FLOW CTRL
5	Low Pressure Switch	LOW PRS SWITCH
6	Refrigerant Clutch Circuit	CLUTCH CIRCUIT
7	Evaporator Thermostat Circuit	—
228	High Pressure Switch	HI PRES SWITCH

10-4

Table 6—Failure Mode Identifiers (FMIs)

FMI	Description and Comments
00	Above normal operating range, for example: engine overheating (required diagnostic information)
01	Below normal operating range, for example: engine oil pressure too low (required diagnostic information)
02	Erratic, intermittent, or incorrect data
03	Voltage above normal or shorted high
04	Voltage below normal or shorted low
05	Current below normal or open circuit
06	Current above normal or circuit shorted to ground
07	Mechanical system not responding properly
08	Abnormal frequency, pulse width, or period
09	Abnormal update rate
10	Abnormal rate of change
11	Failure node not identifiable
12	Bad intelligent device or component
13	Out of calibration
14	Special instructions
15	Reserved for future assignment

All information for Student Supplement 1 provided by Freightliner Inc.

Objective 11

Assignment Sheet 1—Conduct an Operator Survey for Engine Diagnosis

Name ______________________ Overall Rating __________

Date ______________________

Evaluation Criteria	**Rating**
• Answers are correct	______

Basic Skills

Reading Writing Oral Communication Critical Thinking Employability

Introduction

One of the best sources for troubleshooting information is the person who actually operates the vehicle or piece of equipment. This person sees daily how the engine runs in "real life." When things start to go wrong, they are the first to know. If you ask the right questions, they are also your best source of accurate information.

Directions

Ask the operator the questions in Part 1, and then use Part 2 to interpret the answers.

Part 1

Questions	Yes	Comments
1. Does the Check Engine Lamp come ON during or after the problem occurs? —How long does/did it stay ON?		
2. How often does the problem occur? —Can you (driver) take the truck and demonstrate the problem within one hour?		
3. Has the truck been to other shops for the same problem? If so, when and where?		
4. Did the engine completely shutdown, requiring a restart using the ignition key switch? —How long do you have to wait before you can restart it after the shutdown?		
5. Did the engine hesitate/burp/misfire **without** a complete shutdown?		

Assignment Sheet 1

Questions	Yes	Comments
6. Did the radio, dash gauges, or lights momentarily turn OFF when the problem occurred? —Any other observations about truck components?		
7. Does the problem occur only at specific engine loads? —If so, at what load? Is it light, medium, or heavy?		
8. Does the problem occur at a specific **engine** operating temperature? —If so, at what **engine** temperature?		
9. Does the problem occur only when above or below specific **outside** temperatures? —In what temperature range?		
10. Does the problem occur during other conditions (during or after rain or spray washing)?		
11. Did the problem occur at a specific vehicle speed? —If so, at what vehicle speed?		
12. Did the vehicle "kick out" of cruise control or PTO mode(s)?		
13. Does the problem only occur when using the accelerator, not in cruise control or PTO mode(s)?		
14. Does the problem occur at a specific engine rpm? —If so, at what engine rpm?		

Part 2

Response
1. If the Check Engine Light came ON, there will be a logged diagnostic code. Check to see if the driver's indicated symptoms agree with the symptoms associated with the diagnostic code. If the driver's symptoms do not match the symptoms for the diagnostic code, troubleshooting the diagnostic code will not correct the problem. Review the snapshots associated with each diagnostic code to determine the operating conditions of the engine at the time the problem occurred. Try to duplicate these conditions. If there are not any logged diagnostic codes, check the ECM battery connections.
2. If the problem is easily repeatable, take the truck for a drive with an electronic service tool connected and note the conditions when the problem occurs. Be prepared to take snapshot data using the electronic service tool or the cruise control set/resume switches. Make sure you operate the truck after correcting the problem and duplicate the operating conditions before releasing the truck to verify the problem is corrected.
3. If the truck has been to other shops for the same problem, call the other shop and find out what has been done. Avoid replacing the same components again unless absolutely sure they are the problem! It is unlikely a component will fail again following a recent replacement.

Response (Continued)

4. Troubleshoot why the engine won't restart. Repairing the reason for the engine not starting should repair the reason the engine shut down. If the engine shuts down completely, check the ECM battery connections, ground connections, fuel system, fuel, and engine speed/timing sensor.
5. Refer to manufacturer's troubleshooting charts for more information on engine misfiring.
6. If other vehicle devices are affected, there is something wrong with the truck wiring. Refer to manufacturer's troubleshooting charts for inspecting the ECM battery connections.
7. Operate the engine under similar load conditions. Check the low pressure fuel lines for restrictions, fuel/water separator, and fuel tanks for foreign objects blocking the fuel supply.
8. Operate the engine at this temperature while attempting to duplicate the problem.
9. If possible, troubleshoot the problem in this temperature range.
10. If the problem seems to occur during or after the engine is subjected to rain/spray washing, thoroughly inspect the connectors for moisture entry.
11. If the problem occurs at a specific vehicle speed, check parameters affecting vehicle speed to verify they are programmed close to the vehicle speed where the problem occurs. Check vehicle speed limit, VSL protection, low and high cruise speed set limits, idle/PTO vehicle speed limit, and engine/gear parameters. Set each to its maximum value one at a time and verify the problem is corrected.
12. If the vehicle "kicks out" of cruise control or PTO mode and it can be duplicated, check the electronic service tool status screen for cruise, idle, or PTO kickout parameter. If the problem cannot be duplicated, inspect the vehicle speed circuit, service brake switch circuit, clutch switch circuit and switch adjustment, and cruise/idle/PTO On/Off switch circuits as appropriate.
13. Check for logged diagnostic codes associated with the throttle position sensor.
14. If the problem occurs at a specific engine rpm, check programmable VSL protection, idle RPM limit, Top engine limit, PTO top engine limit, and progressive shift parameters. Set each parameter to its maximum value one at a time and verify the problem is corrected.

© Caterpillar Inc. Used with permission

Objective 12

Assignment Sheet 2—Interpret SAE Code Identifiers

Name ______________________ Overall Rating __________

Date ______________________

Evaluation Criteria	Rating
• Answers are correct	______

Basic Skills

Reading Critical Thinking Employability

Introduction

SAE fault codes help you quickly locate malfunctions by narrowing your search. Accurately interpreting what the system is telling you greatly reduces your troubleshooting effort.

Directions

Listed below are six trouble codes. Using Student Supplement 1, identify each of the three segments for each code. Next, using the information given by the three segments of the code identifier, describe the fault.

Example: **128 s100 04**

a.	MID	**128**	Engine
b.	PID/SID	**s110**	Engine Coolant Temperature
c.	FMI:	**04**	Voltage below normal or shorted low
d.	Fault description		Engine temp sensor bad

1. **128 s110 00**
   a. MID ______________________
   b. PID/SID ______________________
   c. FMI ______________________
   d. Fault description ______________________

Assignment Sheet 2

2. **128 s51 02**
   a. MID ______________________________
   b. PID/SID ______________________________
   c. FMI ______________________________
   d. Fault description ______________________________
3. **128 s15 08**
   a. MID ______________________________
   b. PID/SID ______________________________
   c. FMI ______________________________
   d. Fault description ______________________________
4. **128 s76 02**
   a. MID ______________________________
   b. PID/SID ______________________________
   c. FMI ______________________________
   d. Fault description ______________________________
5. **128 s167 00**
   a. MID ______________________________
   b. PID/SID ______________________________
   c. FMI ______________________________
   d. Fault description ______________________________
6. **128 s100 01**
   a. MID ______________________________
   b. PID/SID ______________________________
   c. FMI ______________________________
   d. Fault description ______________________________

Objective 13

Job Sheet 1—Check Air Intake System for Restrictions

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Correct procedures identified for assigned vehicle	______
• Procedures completed correctly	______
• Proper tools used correctly	______
• Safety precautions observed	______
• Installed equipment functions correctly	______
• Serviced equipment meets specifications	______
• Clean-up and follow-up actions adequate	______

Basic Skills

Reading Writing Science Critical Thinking Employability

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, Equipment, and Materials

- Technician's common hand tools
- Appropriate engine service manual
- Job ticket or work order—one is included or use appropriate one provided at your facility
- Safety glasses
- Manometer or magnahelic gauge
- Engine/vehicle to be worked on
- Others—as recommended by instructor and equipment service manual

Guidelines

- Install the manometer as close to the turbocharger inlet as possible.
- Make sure that the air filter has been cleaned/serviced.

Procedure

☐ 1. Locate and follow the appropriate procedure in the service manual.

☐ 2. Complete the accompanying job ticket with all pertinent information.

☐ 3. Set parking brake, remove ignition key, and chock wheels.

☐ 4. Visually inspect all metal ductwork for dents or distortion.

☐ 5. Physically compress flexible rubber couplings, while watching for signs of cracking or deterioration.

☐ 6. Check the tightness of all hose clamps.

☐ 7. Connect the manometer/magnahelic gauge according to the manufacturer's instructions. Ensure that the fitting is at a right angle to the airflow.

☐ 8. Start the engine and operate at required load and speed (if possible).

☐ 9. Record manometer reading on the job ticket.

☐ 10. Allow the engine to idle for five minutes to stabilize cooling system temperatures and allow for turbocharger cool down.

☐ 11. Shut off engine and remove test equipment.

☐ 12. Remove test equipment and reinstall the pipe plug.

☐ 13. Turn in job ticket when finished.

☐ 14. Clean work area and return tools and materials to proper storage.

Evaluator's Comments: ______________________________

____

____

Job Sheet 1

PARTS LIST

QTY.	PARTS/MATERIALS	PRICE	
TOTAL PARTS/MATERIALS			

SPECIFICATIONS CHECKED

School/Work Name ________________________

Address ________________________

Phone # ________________________

Date In ____________

Date Out ____________

JOB TICKET

Customer Name ________________________

Customer Address ________________________

Customer Phone # ________________________

Vehicle/Equip.	Make & Model	License #/Motor #/Serial #	Speedometer

Condition reported by customer/service requested: ________________________

Services/repairs made: ________________________

LABOR	

Customer Authorization

I, the undersigned, have reviewed the required service and parts estimates and authorize this maintenance to be performed with the understanding that I will be notified prior to the performance of any work that significantly exceeds those estimates in time or cost.

________________________ Date ____________

Technician ____________

Supervisor ____________

Objective 14

Job Sheet 2—Check Exhaust Back Pressure

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Correct procedures identified for assigned vehicle	______
• Procedures completed correctly	______
• Proper tools used correctly	______
• Safety precautions observed	______
• Installed equipment functions correctly	______
• Serviced equipment meets specifications	______
• Clean-up and follow-up actions adequate	______

Basic Skills

Reading Writing Science Critical Thinking Employability

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, Equipment, and Materials

- Technician's common hand tools
- Appropriate engine service manual
- Job ticket or work order—one is included or use appropriate one provided at your facility
- Safety glasses
- Manometer or magnahelic gauge
- Engine to be worked on
- Others—as recommended by instructor and equipment service manual

Guidelines

- Readings must be taken at load and rpm specified in the OEM engine service manual.

- Make sure that the air filter has been cleaned/serviced.

Procedure

☐ 1. Locate and follow the appropriate procedure in the service manual.

☐ 2. Complete the accompanying job ticket with all pertinent information.

☐ 3. Set parking brake, remove ignition key, and chock wheels.

☐ 4. Visually inspect the exhaust system for dents or distortion.

☐ 5. Install the manometer/magnahelic gauge as recommended by the manufacturer. Usually this involves:

  ☐ a. If the engine is turbocharged, connect it to a straight section of exhaust pipe near the turbine outlet.

  ☐ b. If the engine is normally aspirated, connect it to the exhaust manifold.

☐ 6. Start the engine and bring to operating temperature.

☐ 7. Run the engine as specified in the engine service manual. Observe the manometer reading and record it on the job ticket.

☐ 8. Allow the engine to idle for five minutes to stabilize cooling system temperatures and allow for turbocharger cool down.

☐ 9. Shut off engine and remove test equipment.

☐ 10. Compare the back pressure reading with the OEM recommendations. If the reading is higher than specified, inspect the muffler for signs of clogging.

☐ 11. Turn in job ticket when finished.

☐ 12. Clean work area and return tools and materials to proper storage.

Evaluator's Comments: ______________________________

____

____

PARTS LIST

QTY.	PARTS/MATERIALS	PRICE
TOTAL PARTS/MATERIALS		

SPECIFICATIONS CHECKED

School/Work Name ____________________
Address ____________________
Phone # ____________________

Date In ____________
Date Out ____________

JOB TICKET

Customer Name ____________________
Customer Address ____________________
Customer Phone # ____________________

Vehicle/Equip.	Make & Model	License #/Motor #/Serial #	Speedometer

Condition reported by customer/service requested: ____________________

Services/repairs made: ____________________

LABOR

Customer Authorization

I, the undersigned, have reviewed the required service and parts estimates and authorize this maintenance to be performed with the understanding that I will be notified prior to the performance of any work that significantly exceeds those estimates in time or cost.

____________________ Date ____________

Technician ____________
Supervisor ____________

Job Sheet 2

Objective 15

Job Sheet 3—Check Crankcase Pressure

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Correct procedures identified for assigned vehicle	______
• Procedures completed correctly	______
• Proper tools used correctly	______
• Safety precautions observed	______
• Installed equipment functions correctly	______
• Serviced equipment meets specifications	______
• Clean-up and follow-up actions adequate	______

Basic Skills

Reading Writing Critical Thinking Employability

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, Equipment, and Materials

- Technician's common hand tools
- Appropriate engine service manual
- Job ticket or work order—one is included or use appropriate one provided at your facility
- Safety glasses
- OEM blow-by inspection tool or manometer/magnahelic gauge and adapters
- Engine to be worked on
- Others—as recommended by instructor and equipment service manual

Guidelines

- Readings must be taken at load and rpm specified in the OEM engine service manual.

- Make sure that the air filter has been cleaned/serviced.

Procedure

☐ 1. Locate and follow the appropriate procedure in the service manual.

☐ 2. Complete the accompanying job ticket with all pertinent information.

☐ 3. Set parking brake, remove ignition key, and chock wheels.

☐ 4. Install the test equipment as recommended by the manufacturer. Typical installation points include:

- Oil fill tube
- Dipstick tube
- Crankcase vent

☐ 5. Start engine and bring to operating temperature.

☐ 6. Run the engine as specified in the engine service manual. Observe the manometer reading and record it on the job ticket.

☐ 7. Allow the engine to idle for five minutes to stabilize cooling system temperatures and allow for turbocharger cool down.

☐ 8. Shut off engine and remove test equipment.

☐ 9. Compare the crankcase pressure reading with the OEM recommendations. If the reading is higher than specified, excessive blow-by is present in one or more cylinders.

☐ 10. Turn in job ticket when finished.

☐ 11. Clean work area and return tools and materials to proper storage.

Evaluator's Comments: ______________________________

____

____

PARTS LIST

QTY.	PARTS/MATERIALS	PRICE
TOTAL PARTS/MATERIALS		

SPECIFICATIONS CHECKED

School/Work Name
Address
Phone #

Date In
Date Out

JOB TICKET

Customer Name
Customer Address
Customer Phone #

Vehicle/Equip.	Make & Model	License #/Motor #/Serial #	Speedometer

Condition reported by customer/service requested:

Services/repairs made:

LABOR

Customer Authorization

I, the undersigned, have reviewed the required service and parts estimates and authorize this maintenance to be performed with the understanding that I will be notified prior to the performance of any work that significantly exceeds those estimates in time or cost.

Date

Technician
Supervisor

Job Sheet 3

Objective 16

Job Sheet 4—Check Oil Pressure

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Correct procedures identified for assigned vehicle	______
• Procedures completed correctly	______
• Proper tools used correctly	______
• Safety precautions observed	______
• Installed equipment functions correctly	______
• Serviced equipment meets specifications	______
• Clean-up and follow-up actions adequate	______

Basic Skills

Reading Writing Critical Thinking Employability

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, Equipment, and Materials

- Technician's common hand tools
- Appropriate engine service manual
- Job ticket or work order—one is included or use appropriate one provided at your facility
- Safety glasses
- Master shop oil pressure gauge and adapters
- Engine to be worked on
- Others—as recommended by instructor and equipment service manual

Guidelines

- Readings must be taken at load and rpm specified in the OEM engine service manual.

- Make sure that the oil level in the crankcase is correct.

- Check service logs to ensure that oil and filter condition is adequate for an accurate test.

Procedure

☐ 1. Locate and follow the appropriate procedure in the service manual.

☐ 2. Complete the accompanying job ticket with all pertinent information.

☐ 3. Set parking brake and chock wheels.

☐ 4. Connect the master shop gauge to the engine oil galley as stated in the OEM engine service manual.

☐ 5. Start the engine and bring to operating temperature.

☐ 6. Run the engine at the speeds called for in the manual. Note the pressure readings on the master shop gauge; record them on the job ticket.

☐ 7. Allow the engine to idle for five minutes to stabilize cooling system temperatures and allow for turbocharger cool down.

☐ 8. Shut off engine and remove test equipment.

☐ 9. Remove the test gauge and reinsert the pipe plug.

☐ 10. Turn in job ticket when finished.

☐ 11. Clean work area and return tools and materials to proper storage.

Evaluator's Comments: ______________________________

____

____

Job Sheet 4

PARTS LIST

QTY.	PARTS/MATERIALS	PRICE	
TOTAL PARTS/MATERIALS			

SPECIFICATIONS CHECKED

School/Work Name ____________________

Address ____________________

Phone # ____________________

Date In ____________

Date Out ____________

JOB TICKET

Customer Name ____________________

Customer Address ____________________

Customer Phone # ____________________

Vehicle/Equip.	Make & Model	License #/Motor #/Serial #	Speedometer

Condition reported by customer/service requested: ____________________

Services/repairs made: ____________________

LABOR	

Customer Authorization

I, the undersigned, have reviewed the required service and parts estimates and authorize this maintenance to be performed with the understanding that I will be notified prior to the performance of any work that significantly exceeds those estimates in time or cost.

____________________ Date ____________

Technician ____________

Supervisor ____________

Objective 17

Job Sheet 5—Load Test an Engine on a Dynamometer

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Correct procedures identified for assigned vehicle	______
• Procedures completed correctly	______
• Proper tools used correctly	______
• Safety precautions observed	______
• Installed equipment functions correctly	______
• Serviced equipment meets specifications	______
• Clean-up and follow-up actions adequate	______

Basic Skills

Reading Writing Science Critical Thinking Employability

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, Equipment, and Materials

- Technician's common hand tools
- Appropriate engine service manual
- Job ticket or work order—one is included or use appropriate one provided at your facility
- Safety glasses
- Dynamometer
- Oil pressure gauge
- Water temperature gauge
- Pressure gauge or water manometer with adapters
- Fuel pressure gauge
- Engine/vehicle to be worked on
- Others—as recommended by instructor and equipment service manual

Guidelines

- If using a chassis dyno, be sure that the drive wheels are positioned correctly, and that the vehicle is secured according to the manufacturer's instructions.

- If using a portable dyno, be sure that the connections are correct and tight.

Procedure

☐ 1. Locate and follow the appropriate procedure in the service manual.

☐ 2. Complete the accompanying job ticket with all pertinent information.

☐ 3. Locate the engine performance specifications in the engine service manual. Record them below:

Rated load speed ________________

Rated horsepower ________________

High idle ________________________

☐ 4. Start the engine and bring to operating temperature. (Running the engine at a light load will do this more quickly.)

☐ 5. Using the dynamometer load control, gradually increase the load on the engine until engine rpm drops to the rated load speed you recorded in step 3.

☐ 6. Note the horsepower reading on the dynamometer. Record it here.

Indicated speed (dyno) ___________________

Indicated horsepower (dyno) ______________

☐ 7. While the engine is operating under load, remove the oil filler cap and check crankcase vapor output. A small amount of vapor is acceptable; columns of smoke/vapor are considered excessive and require attention. (See Job Sheet 1)

☐ 8. Gradually decrease the load on the engine, then bring the engine back to idle. Allow the engine to idle for five minutes to stabilize cooling system temperatures and allow for turbocharger cool down.

☐ 9. Shut off engine and remove the test equipment.

☐ 10. Using your horsepower figures from step 6, perform the required conversion to allow for temperature differences in your shop. This gives corrected horsepower. Record it here:

Corrected horsepower _____________

This horsepower figure compares directly to the factory rated horsepower from step 3. Actual horsepower figures usually don't match rated horsepower figures exactly. If the difference between corrected horsepower and rated horsepower is greater than 5%, further troubleshooting is necessary.

☐ 11. Turn in job ticket when finished.

☐ 12. Clean work area and return tools and materials to proper storage.

Evaluator's Comments: ____________________

____

____

1049

PARTS LIST

QTY.	PARTS/MATERIALS	PRICE	
TOTAL PARTS/MATERIALS			

SPECIFICATIONS CHECKED

School/Work Name ______________________________

Address ______________________________

Phone # ______________________________

Date In ______________

Date Out ______________

JOB TICKET

Customer Name ______________________________

Customer Address ______________________________

Customer Phone # ______________________________

Vehicle/Equip.	Make & Model	License #/Motor #/Serial #	Speedometer

Condition reported by customer/service requested: ______________________________

____

Services/repairs made: ______________________________

____

____

____

____

____

____

____

____

____

____

____

LABOR	

Customer Authorization

I, the undersigned, have reviewed the required service and parts estimates and authorize this maintenance to be performed with the understanding that I will be notified prior to the performance of any work that significantly exceeds those estimates in time or cost.

______________________________ Date ______________

Technician ______________

Supervisor ______________

Objective 18

Job Sheet 6—Locate a Misfiring Cylinder

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Correct procedures identified for assigned vehicle	______
• Procedures completed correctly	______
• Proper tools used correctly	______
• Safety precautions observed	______
• Misfiring cylinder identified correctly	______
• Clean-up and follow-up actions adequate	______

Basic Skills

Reading Writing Science Critical Thinking Employability

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, Equipment, and Materials

- Technician's common hand tools
- Appropriate engine service manual
- Job ticket or work order—one is included or use appropriate one provided at your facility
- Safety glasses
- Dynamometer
- Contact pyrometer
- Temp-a-Stik™ thermomelt crayons
- Shop towels
- Engine/vehicle to be worked on
- Others—as recommended by instructor and equipment service manual

Guidelines

- Exhaust manifold surfaces get hot quickly; use care in working around them.
- If using a chassis dyno to load the engine, be sure that the drive wheels are positioned correctly and that the vehicle is secured according to manufacturer's instructions.
- If using a portable dyno to load the engine, be sure that the connections are correct and tight.

Procedure

☐ 1. Locate and follow the appropriate procedure in the service manual.

☐ 2. Complete the accompanying job ticket with all pertinent information.

☐ 3. Set the parking brake and chock the wheels.

☐ 4. There are several methods used to locate a misfiring cylinder. This job sheet contains procedures for each one.

  ☐ a. **Method One** (Used on all engines, but only when cold)

  - Start the engine.
  - Immediately place your hand on the manifold runners close to the cylinder head.
  - Alternate between manifolds, feeling for temperature change.
  - Locate the misfiring cylinder by noting which manifold runner stays cool while the rest of the runners get warmer.
  - Note the misfiring cylinder on the job ticket.

  ☐ b. **Method Two** (Used on all engines)

  - If a dynamometer is available, connect it according to the manufacturer's instructions. If a dynamometer is not available, proceed to Method 3.
  - Start the engine and allow it to warm up.
  - Load the engine by either using the dynamometer or by snapping the throttle open quickly several times.
  - Use either a pyrometer or a thermomelt crayon to measure the temperature of the exhaust manifold runners.
  - If using a pyrometer, note the pyrometer readings. If using a crayon, note which exhaust manifold runner does not melt the crayon. This indicates the misfiring cylinder.
  - Note the misfiring cylinder on the job ticket.

  ☐ c. **Method Three** (Used on engines equipped with pump-and-nozzle injection)

  - Start the engine and allow it to warm up.
  - Wrap a towel around the #1 injection line at the injector. (This will absorb leaking fuel.)

1053

- Loosen ("crack") the fitting to stop the fuel flow to #1 injector. Listen for a change in the sound of the engine. If the sound changes and the engine speed slows down, the cylinder is firing.
- Tighten the fitting. Wipe it with a dry shop towel, be sure the fitting is tight and leak-free.

  Note: The change in sound can be accentuated by loading the engine. This can be done either with a dynamometer or by snapping open the throttle quickly several times.
- Repeat the step for each cylinder. The misfiring cylinder is located when "cracking" the line produces no change in either engine speed or engine sound.
- Note the misfiring cylinder on the job ticket.

☐ 5. Shut off the engine and remove the dyno equipment (if used).

☐ 6. Turn in job ticket when finished.

☐ 7. Clean work area and return tools and materials to proper storage.

Evaluator's Comments: ____________________________________

____

____

PARTS LIST

QTY.	PARTS/MATERIALS	PRICE	
TOTAL PARTS/MATERIALS			

SPECIFICATIONS CHECKED

School/Work Name ______

Address ______

Phone # ______

Date In ______

Date Out ______

JOB TICKET

Customer Name ______

Customer Address ______

Customer Phone # ______

Vehicle/Equip.	Make & Model	License #/Motor #/Serial #	Speedometer

Condition reported by customer/service requested: ______

Services/repairs made: ______

LABOR	

Customer Authorization

I, the undersigned, have reviewed the required service and parts estimates and authorize this maintenance to be performed with the understanding that I will be notified prior to the performance of any work that significantly exceeds those estimates in time or cost.

______ Date ______

Technician ______

Supervisor ______

Objective 19

Job Sheet 7—Locate an Active Fault Code

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Correct procedures identified for assigned vehicle	______
• Procedures completed correctly	______
• Proper tools used correctly	______
• Safety precautions observed	______
• Active fault identified correctly	______
• Clean-up and follow-up actions adequate	______

Basic Skills

Reading Writing Science Critical Thinking Employability

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, Equipment, and Materials

- Technician's common hand tools
- Appropriate engine service manual
- Job ticket or work order—one is included or use appropriate one provided at your facility
- Appropriate engine diagnostic unit/analyzer
- Configuration modules and test harnesses as required
- Engine/vehicle to be worked on
- Others—as recommended by instructor and equipment service manual

Guidelines

- When installing program modules/cartridges, use only finger pressure. Never use screwdrivers or pliers to grip or pry.
- Be sure that the engine is off before connecting or disconnecting the diagnostic unit.
- When using a magnetic timing sensor, be sure that the tip is free of metal particles and debris.
- Route all test harnesses/cables away from sources of heat (exhaust manifold) or moving components (fan blade, pulleys).

Procedure

☐ 1. Locate and follow the appropriate procedure in the service manual.

☐ 2. Complete the accompanying job ticket with all pertinent information.

☐ 3. Set parking brake, turn off engine, and chock wheels.

☐ 4. Install the correct module/cartridge for the vehicle series being tested.

☐ 5. Install the timing sensor according to the manufacturer's instructions. Make sure that there is sufficient clearance between the tip of the probe and the crankshaft/ flywheel/harmonic balancer.

☐ 6. Install the test harness(es) according to the manufacturer's instructions.

☐ 7. Turn on the diagnostic unit.

☐ 8. Start the engine and allow it to come up to operating temperature.

Note: Most scan tools are menu-driven. You will be using the function for displaying fault codes.

☐ 9. Select the appropriate screen to view active fault codes. Run the procedure as required. List any codes that appear below. Also record on job ticket.

____

____

____

____

☐ 10. If necessary, allow the engine to idle for several minutes before shutting it down.

☐ 11. Disconnect the test harness(es), and remove the timing probe. Reinstall the timing plug (if removed).

☐ 12. Use the SAE code identifiers in Student Supplement 1 to identify the faults you have detected. Record on job ticket.

☐ 13. Turn in job ticket when finished.

☐ 14. Clean work area and return tools and materials to proper storage.

Evaluator's Comments: ______________________________

____

____

PARTS LIST

QTY.	PARTS/MATERIALS	PRICE	
TOTAL PARTS/MATERIALS			

SPECIFICATIONS CHECKED

School/Work Name ____________________

Address ____________________

Phone # ____________________

Date In __________

Date Out __________

JOB TICKET

Customer Name ____________________

Customer Address ____________________

Customer Phone # ____________________

Vehicle/Equip.	Make & Model	License #/Motor #/Serial #	Speedometer

Condition reported by customer/service requested: ____________________

Services/repairs made: ____________________

LABOR	

Customer Authorization

I, the undersigned, have reviewed the required service and parts estimates and authorize this maintenance to be performed with the understanding that I will be notified prior to the performance of any work that significantly exceeds those estimates in time or cost.

____________________ Date __________

Technician __________

Supervisor __________

1060

Job Sheet 7

Unit Contents

Student Components

Student Page

Objective Sheet 2D-3

Information Sheet 2D-5

Student Supplements

1—Example of Vehicle Engine Preventive Maintenance Schedule 2D-9
2—Example of Off-Road Equipment Preventive Maintenance Schedule 2D-15
3—Example of Stationary Preventive Maintenance Schedule 2D-17
4—Example of Flowchart Style Maintenance Troubleshooting Chart 2D-23
5—Example of Narrative Style Maintenance Troubleshooting Chart 2D-25

Assignment Sheets

1—Determine Maintenance Needed for Given Situations 2D-27
2—Interpret Maintenance Troubleshooting Charts 2D-31

Job Sheets

1—Inspect Engine Coolant Level and Condition 2D-33
2—Pressure Test Coolant System and Radiator Cap 2D-37
3—Take Oil Sample, and Change Oil and Filter(s) 2D-41
4—Inspect and Test Indicator System Components 2D-45
5—Perform a Daily Preventive Maintenance Check 2D-49
6—Perform a Mileage Preventive Maintenance Check 2D-53
7—Perform an Engine Tune-Up 2D-59

Unit 2-D Preventive Maintenance and Tune-Up

Objective Sheet

Unit Objective

After completing this unit, the student should be able to perform daily and mileage preventive maintenance checks, as well as perform an engine tune-up. The student should demonstrate these competencies by completing the job sheets and by scoring a minimum of 85 percent on the written test.

Specific Objectives

After completing this unit, the student should be able to:

1. Match terms related to preventive maintenance and tune-up with their definitions.
2. Distinguish between purposes of preventive maintenance and tune-up.
3. Complete statements on locating preventive maintenance charts and information.
4. List ways of designating preventive maintenance intervals.
5. Select from a list conditions that require severe service maintenance schedules.
6. Describe engine areas requiring preventive maintenance.
7. Complete statements concerning preventive maintenance tasks for diesel fuel systems.
8. Arrange in sequence the maintenance steps for a diesel engine tune-up.
9. Determine maintenance needed for given situations. (Assignment Sheet 1)
10. Interpret maintenance troubleshooting charts. (Assignment Sheet 2)
11. Inspect engine coolant level and condition. (Job Sheet 1)
12. Pressure test coolant system and radiator cap. (Job Sheet 2)
13. Take oil sample, and change oil and filter(s). (Job Sheet 3)
14. Inspect and test indicator system components. (Job Sheet 4)
15. Perform a daily preventive maintenance check. (Job Sheet 5)
16. Perform a mileage preventive maintenance check. (Job Sheet 6)
17. Perform an engine tune-up. (Job Sheet 7)

Information Sheet

Objective 1

Terms and definitions

a. **Biocide**—Chemical that kills microorganisms such as bacteria and fungi that may be found in fuel tanks

b. **Check**—Inspection or examination of certain items to verify their condition

c. **Hubmeter**—Mileage counter mounted on a rear drive hub

d. **Interval**—Span of time between events (such as oil changes, fuel line inspections, etc.)

e. **Log**—Collection of written information concerning the operation, maintenance, and repair records for a given vehicle, engine, or piece of equipment; usually kept in a notebook or binder

f. **OTR (over the road)**—Term applied to long-distance trucking

g. **Preventive maintenance (PM)**—Systematic and periodic inspection and servicing of vehicles and their components

h. **Schedule**—Plan that indicates the time and sequence of each operation in a procedure

i. **Severe service**—Use of a vehicle or other equipment under conditions that are harsh, extreme, or require great effort

j. **Symptom**—Indication of mechanical or electrical trouble

k. **Tune-up**—Checks and adjustment of engine components back to manufacturer's specifications

Objective 2

Purposes of preventive maintenance and tune-up

a. Purposes of preventive maintenance

- To detect and correct problems
- To prevent costly failures and breakdowns
- To ensure optimum component life

b. Purposes of tune-up

- To correct for wear
- To obtain optimum engine performance

Objective 3

Locating preventive maintenance charts and information

a. May be located in the manufacturers' operation and maintenance manuals or included as a separate section of the engine manufacturers' service manual

b. May also be available as supplements to some engine manufacturers' manuals

Objective 4

Ways of designating preventive maintenance intervals

a. **By time or duty cycle**

Examples: Daily, weekly, monthly, yearly (annually)

b. **By service hours**

Examples: 250 hours, 1000 service hours

c. **By mileage** (odometer or hubmeter)

Examples: 9,000 miles (14,400 km), 22,500 miles (36,000 km)

d. **By fuel consumption**—For stationary and off-road applications; may be measured by weight or volume

Note: PM intervals will vary depending on the manufacturer and the application. Many companies refer to PM inspections as A, B, or C checks, but the intervals vary between companies. For example, an "A" check may be 6,000 miles in one company but 12,000 miles in another. The type of service (severe, medium, or OTR) will also affect the PM service interval.

Objective 5

Conditions that require severe service maintenance schedules

a. Subzero operation (regular cold starts at temperatures below 0° F)

b. High altitude operation (above 5,000 feet)

c. Off-highway operation

d. Operation with gross vehicle weights over 80,000 pounds

e. Extended operation at low idle

f. Frequent hot shutdowns (minimum five minute cool down after high load operation)

Objective 6

Engine areas requiring preventive maintenance

a. **Air intake and exhaust system**

- Ducting
- Intercooler
- Turbocharger/supercharger

b. **Cooling system**

- Coolant condition and level
- Coolant filters
- Radiator
- Belts and hoses
- Fan hub and clutch
- Water pump
- Thermostat
- Heater

c. **Electrical system (engine accessory)**

- Battery
- Alternator
- Starter
- Cables/wiring harness

d. **Fuel system**

- Tanks
- Lines
- Filters
- Pump
- Injectors/injector pump
- Throttle linkage

e. **Lubricating system**

- Oil condition and level
- Oil filters/screens
- Pump (system pressure)

f. **Engine fasteners**

- Mounting bolts
- Housings
- Hold-downs

Note: Other checks will also be performed in addition to these engine checks, such as checks on the brakes, chassis, cab, and tires/wheels.

Objective 7

Preventive maintenance tasks for diesel fuel systems

a. Fill fuel tanks at the end of each day to minimize condensation.

b. Drain water/sediment weekly.

c. Add biocide if needed.

Objective 8

Diesel engine tune-up sequence

a. Adjust valves.

b. Adjust injectors.

c. Adjust slave piston lash (Jake Brake®) (if required).

Student Supplement 1—Example of Vehicle Engine Preventive Maintenance Schedule

13.2 DAILY MAINTENANCE—ALL APPLICATIONS

The following items need to be inspected, serviced, corrected or replaced on a daily basis, as necessary:

- ☐ Lubricating oil, refer to section 13.5.1.
- ☐ Fuel tank, refer to section 13.5.2.
- ☐ Fuel lines and Flexible hoses, refer to section 13.5.3.
- ☐ Cooling system, refer to section 13.5.4.
- ☐ Turbocharger, refer to section 13.5.5.

13.3 MAINTENANCE OF VEHICLE ENGINES

Vehicle engine components must be maintained at various intervals.

13.3.1 7,500 Mile (12,000 km) Interval Maintenance

Every 7,500 miles (12,000 km), the following components must be inspected, serviced, corrected or replaced as necessary.

- ☐ Battery, refer to section 13.5.6
- ☐ Drive belts, refer to section 13.5.8
- ☐ Air compressor, refer to section 13.5.9

13.3.2 15,000 Mile (24,000 km) or 6 Month Interval Maintenance

Every 15,000 miles (24,000 km) or 6 months, the following components must be inspected, serviced, corrected or replaced as necessary.

- ☐ Tachometer drive, refer to section 13.5.7
- ☐ Air cleaner, refer to section 13.5.10

Likewise, the following components must be replaced every 15,000 miles (24,000 km) or 6 months.

- ☐ Lubricating oil, refer to section 13.5.1
- ☐ Lubricating oil filter, refer to section 13.5.11
- ☐ Fuel filter, refer to section 13.5.12
- ☐ Coolant filter and inhibitor, refer to section 13.5.13

13.3.3. 30,000 Mile (48,000 km) or 12 Month Interval Maintenance

Every 30,000 miles (48,000 km) or 12 months, the following components must be inspected, serviced, corrected or replaced as necessary.

- ☐ Fuel tank, refer to section 13.5.2
- ☐ Tachometer drive, refer to section 13.5.7
- ☐ Drive belts, refer to section 13.5.8
- ☐ Air compressor, refer to section 13.5.9
- ☐ Air system, refer to section 13.5.15
- ☐ Exhaust system, refer to section 13.5.16
- ☐ Engine (steam clean), refer to section 13.5.17
- ☐ Radiator and air-to-air charge cooler, refer to section 13.5.18
- ☐ Battery charging alternator, refer to section 13.5.20

Likewise, the following components must be replaced every 30,000 miles (48,000 km) or 12 months.

- ☐ Lubricating oil, refer to section 13.5.1
- ☐ Lubricating oil filter, refer to section 13.5.11
- ☐ Fuel filter, refer to section 13.5.12
- ☐ Coolant filter and inhibitor, refer to section 13.5.13

13.3.4 45,000 Mile (72,000 km) or 18 Month Interval Maintenance

Every 45,000 miles (72,000 km) or 18 months, the following components must be inspected, serviced, corrected or replaced as necessary.

- ☐ Tachometer drive, refer to section 13.5.7
- ☐ Drive belts, refer to section 13.5.8
- ☐ Air compressor, refer to section 13.5.9
- ☐ Air system, refer to section 13.5.15
- ☐ Exhaust system, refer to section 13.5.16

Likewise, the following components must be replaced every 45,000 miles (72,000 km) or 18 months.

- ☐ Lubricating oil, refer to section 13.5.1
- ☐ Lubricating oil filter, refer to section 13.5.11
- ☐ Fuel filter, refer to section 13.5.12
- ☐ Coolant filter and inhibitor, refer to section 13.5.13

13.3.5 60,000 Miles (96,000 km) or 24 Month Interval Maintenance

Every 60,000 miles (96,000 km) or 24 months, the following components must be inspected, serviced, corrected or replaced as necessary.

- ☐ Fuel tank, refer to section 13.5.2
- ☐ Cooling system, refer to section 13.5.4
- ☐ Tachometer drive, refer to section 13.5.7
- ☐ Drive belts, refer to section 13.5.8
- ☐ Air compressor, refer to section 13.5.9
- ☐ Air system, refer to section 13.5.15
- ☐ Exhaust system, refer to section 13.5.16
- ☐ Engine (steam clean), refer to section 13.5.17
- ☐ Radiator and air-to-air charge cooler, refer to section 13.5.18
- ☐ Oil pressure, refer to section 13.5.19
- ☐ Battery charging alternator, refer to section 13.5.20
- ☐ Engine and transmission mounts, refer to section 13.5.21
- ☐ Crankcase pressure, refer to section 13.5.22
- ☐ Thermostats and seals, refer to section 13.5.24
- ☐ Crankcase breather, refer to section 13.5.25

Likewise, the following components must be replaced every 60,000 miles (96,000 km) or 24 months.

- ☐ Lubricating oil, refer to section 13.5.1
- ☐ Lubricating oil filter, refer to section 13.5.11
- ☐ Fuel filter, refer to section 13.5.12
- ☐ Coolant filter and inhibitor, refer to section 13.5.13

13.3.6 75,000 Miles (120,000 km) or 30 Month Interval Maintenance

Every 75,000 miles (120,000 km) or 30 months, the following components must be inspected, serviced, corrected or replaced as necessary.

- ☐ Tachometer drive, refer to section 13.5.7
- ☐ Drive belts, refer to section 13.5.8
- ☐ Air compressor, refer to section 13.5.9
- ☐ Air system, refer to section 13.5.15
- ☐ Exhaust system, refer to section 13.5.16

Likewise, the following components must be replaced every 75,000 miles (120,000 km) or 30 months.

- ☐ Lubricating oil, refer to 13.5.1
- ☐ Lubricating oil filter, refer to section 13.5.11
- ☐ Fuel filter, refer to section 13.5.12
- ☐ Coolant filter and inhibitor, refer to section 13.5.13

13.3.7 90,000 Miles (144,000 km) or 36 Month Interval Maintenance

Every 90,000 miles (144,000 km) or 36 months, the following components must be inspected, serviced, corrected or replaced as necessary.

- ☐ Fuel tank, refer to section 13.5.2
- ☐ Tachometer drive, refer to section 13.5.7
- ☐ Drive belts, refer to section 13.5.8
- ☐ Air compressor, refer to section 13.5.9
- ☐ Air system, refer to section 13.5.15
- ☐ Exhaust system, refer to section 13.5.16
- ☐ Engine (steam clean), refer to section 13.5.17
- ☐ Radiator and air-to-air charge cooler, refer to section 13.5.18
- ☐ Battery charging alternator, refer to section 13.5.20

Likewise, the following components must be replaced every 90,000 miles (144,000 km) or 36 months.

- ☐ Lubricating oil, refer to section 13.5.1
- ☐ Lubricating oil filter, refer to section 13.5.11
- ☐ Fuel filter, refer to section 13.5.12
- ☐ Coolant filter and inhibitor, refer to section 13.5.13

13.3.8 105,000 Miles (168,000 km) or 42 Month Interval Maintenance

Every 105,000 miles (168,000 km) or 42 months, the following components must be inspected, serviced, corrected or replaced as necessary.

- ☐ Tachometer drive, refer to section 13.5.7
- ☐ Drive belts, refer to section 13.5.8
- ☐ Air compressor, refer to section 13.5.9
- ☐ Air system, refer to section 13.5.15
- ☐ Exhaust system, refer to section 13.5.16

Likewise, the following components must be replaced every 105,000 miles (168,000 km) or 42 months.

- ☐ Lubricating oil, refer to section 13.5.1
- ☐ Lubricating oil filter, refer to section 13.5.11
- ☐ Fuel filter, refer to section 13.5.12
- ☐ Coolant filter and inhibitor, refer to section 13.5.13

13.3.9 120,000 Miles (192,000 km) or 48 Month Interval Maintenance

Every 120,000 miles (192,000 km) or 48 months, the following components must be inspected, serviced, corrected or replaced as necessary.

- ☐ Fuel tank, refer to section 13.5.2
- ☐ Cooling system, refer to section 13.5.4
- ☐ Tachometer drive, refer to section 13.5.7
- ☐ Air compressor, refer to section 13.5.9
- ☐ Air system, refer to section 13.5.15
- ☐ Exhaust system, refer to section 13.5.16
- ☐ Engine (steam clean), refer to section 13.5.17
- ☐ Radiator and air-to-air charge cooler, refer to section 13.5.18
- ☐ Oil pressure, refer to section 13.5.19
- ☐ Battery charging alternator, refer to section 13.5.20
- ☐ Engine and transmission mounts, refer to section 13.5.21
- ☐ Crankcase pressure, refer to section 13.5.22
- ☐ Fan Hub, refer to section 13.5.22
- ☐ Thermostats and seals, refer to section 13.5.24
- ☐ Crankcase breather, refer to section 13.5.25
- ☐ Engine Tune-up, refer to section 13.5.26

Likewise, the following components must be replaced every 120,000 miles (192,000 km) or 48 months.

- ☐ Drive belts, refer to section 13.5.8
- ☐ Lubricating oil, refer to section 13.5.1
- ☐ Lubricating oil filter, refer to section 13.5.11
- ☐ Fuel filter, refer to section 13.5.12
- ☐ Coolant filter and inhibitor, refer to section 13.5.13

13.3.10 135,000 Miles (216,000 km) or 54 Month Interval Maintenance

Every 135,000 miles (216,000 km) or 54 months, the following components must be inspected, serviced, corrected or replaced as necessary.

- ☐ Tachometer drive, refer to section 13.5.7
- ☐ Drive belts, refer to section 13.5.8
- ☐ Air compressor, refer to section 13.5.9
- ☐ Air system, refer to section 13.5.15
- ☐ Exhaust system, refer to section 13.5.16

Likewise, the following components must be replaced every 135,000 miles (216,000 km) or 54 months.

- ☐ Lubricating oil, refer to section 13.5.1
- ☐ Lubricating oil filter, refer to section 13.5.11
- ☐ Fuel filter, refer to section 13.5.12
- ☐ Coolant filter and inhibitor, refer to section 13.5.13

13.3.11 150,000 Miles (240,000 km) or 60 Month Interval Maintenance

Every 150,000 miles (240,000 km) or 60 months, the following components must be inspected, serviced, corrected or replaced as necessary.

- ☐ Fuel tank, refer to section 13.5.2
- ☐ Tachometer drive, refer to section 13.5.7
- ☐ Drive belts, refer to section 13.5.8
- ☐ Air compressor, refer to section 13.5.9
- ☐ Air system, refer to section 13.5.15
- ☐ Exhaust system, refer to section 13.5.16
- ☐ Engine (steam, clean), refer to section 13.5.17
- ☐ Radiator and air-to-air charge cooler, refer to section 13.5.18
- ☐ Battery charging alternator, refer to section 13.5.20

Likewise, the following components must be replaced every 150,000 miles (240,000 km) or 60 months.

- ☐ Lubricating oil, refer to section 13.5.1
- ☐ Lubricating oil filter, refer to section 13.5.11
- ☐ Fuel filter, refer to section 13.5.12
- ☐ Coolant filter and inhibitor, refer to section 13.5.13

Courtesy of Detroit Diesel Corporation

Student Supplement 2—Example of Off-Road Equipment Preventive Maintenance Schedule

Item	Service	Lube.	Page
When Required			
Engine Air Intake System	Change filters when yellow diaphgram enters red zone in the indicator or excessive black smoke is observed.		70
Fuel Filter	Change filters when cab indicator light comes on. For normal change period, see 500 service hours.		91
Ether Starting Aid Cylinder (if equipped)	Change ether cylinder when empty.		72
Batteries	Inspect.		72
Cutting Edges and End Bits	Change if damaged or excessively worn.		73
Ripper Tip and Shank Protector	Change if damaged or excessively worn.		74
Power Train Oil System	Clean scavenge line screens at time of repair of transmission, torque converter or steering clutches.	CD/TO-2	74
Equalizer Bar Center Pin	Check if loose or if wear is suspected.		75
Every 10 Service Hours or Daily			
Engine Crankcase Oil	Measure oil level.	CD or CD/TO-2	76
Power Train Oil System	Measure oil level and check for leaks.	CD/TO-2	76
Engine Cooling System	Look at coolant level		77
Hydraulic System Oil	Look at oil level and check for leaks.	HYDO	78
Tracks	Inspect for proper adjustment.		78
Fuel Tank	Drain water and sediment.		79
Walk-Around Inspection	Inspect machine.		79
Electronic Monitoring System and Gauges	Check for broken or inoperative components.		80
Fire Suppression (if equipped)	Check.		80
Seat Belt	Inspect for damage and wear.		80

Item	Service	Lube.	Page
Every 50 Service Hours or Weekly			
Recoil Spring Oil Compartment	Look at the oil level.	CC, CD or CD/TO-2	81
Ripper LInkage and Cylinder Bearings	Lubricate fittings.	MPGM	81
Tracks	Inspect the tracks weekly.		82
Cab Air Filter Elements	Clean the filter elements.		82
Every 250 Service Hours or Monthly			
Engine Crankcase Oil and Filters	Change oil and filters.	CD or CD/TO-2	83
Alternator and Air Conditioner Belts	Measure—replace and/or adjust.		84
Brakes	Test.		85
Tracks	Adjust the tracks if necessary.	MPGM	85
Coolant Conditioner	Add conditioner.		86
Equalizer Bar End Pins	Lubricate fittings.	MPGM	87
Final Drive Oil	Look at oil level.	CC, CD or CD/TO-2	87
Every 500 Service Hours or 3 Months			
Power Train Oil Filters	Change the filter elements.	CD/TO-2	88
Hydraulic System Filter	Change the filter element.	HYDO	89
Engine Crankcase Oil Breather	Wash the breather.		90
Equalizer Bar Pads	Inspect.		90
Fuel Tank Cap and Screen	Wash the cap element and screen.		91
Fuel Filters	Change secondary—wash primary.		91
Every 1000 Service Hours or 6 Months			
Rollover Protection Structure (ROPS)	Retighten the mounting bolts		94
Lift Cylinder Yoke Bearings	Lubricate fittings.	MPGM	94
Power Train Oil System	Change the oil. Wash breather.	CD/TO-2	95
Every 2000 Service Hours or 1 Year			
Final Drive Oil	Look at oil levels.	CC, CD or CD/TO-2	96
Engine Valve Lash	Measure—adjust if necessary		96
Engine Valve Rotators	Observe rotation.		97
Hydraulic System Oil	Change the oil.	HYDO	97
Cooling System Coolant	Change the coolant.		98

© Caterpillar Inc. Used with permission

1074

Student Supplement 3—Example of Stationary Equipment Preventive Maintenance Schedule

13.4 MAINTENANCE OF ENGINES USED IN STATIONARY AND INDUSTRIAL APPLICATIONS

Engine components used in stationary and industrial applications must be maintained at various intervals.

13.4.1 100 Hours (3,000 miles—4,800 km) Maintenance

Every 100 hours (3,000 miles—4,800 km), the following components must be inspected, serviced, corrected or replaced as necessary.

- ☐ Battery, refer to section 13.5.6
- ☐ Drive belts, refer to section 13.5.8

13.4.2 150 Hours (4,500 miles—7,200 km) Maintenance

Every 150 hours (4,500 miles—7,200 km), the following components must be inspected, serviced, corrected, or replaced as necessary.

- ☐ Tachometer drive, refer to section 13.5.7
- ☐ Air compressor, refer to section 13.5.9
- ☐ Air cleaner, refer to section 13.5.10

Likewise, the following components must be replaced every 150 hours (4,500 miles—7,200 km).

- ☐ Lubricating oil, refer to section 13.5.1
- ☐ Lubricating oil filter, refer to section 13.5.11
- ☐ Fuel filter, refer to section 13.5.12
- ☐ Coolant filter and inhibitor, refer to section 13.5.13

13.4.3 300 Hours (9,000 miles—14,400 km) Maintenance

Every 300 hours (9,000 miles—14,400 km) the following components must be inspected, serviced, corrected or replaced as necessary.

- ☐ Fuel tank, refer to section 13.5.2
- ☐ Tachometer drive, refer to section 13.5.7
- ☐ Air compressor, refer to section 13.5.9
- ☐ Air system, refer to section 13.5.15
- ☐ Exhaust system, refer to section 13.5.16
- ☐ Engine (steam clean), refer to section 13.5.17
- ☐ Radiator and air-to-air charge cooler, refer to section 13.5.18
- ☐ Battery charging alternator, refer to section 13.5.20

Likewise, the following components must be replaced every 300 hours (9,000 miles).

- ☐ Lubricating oil, refer to section 13.5.1
- ☐ Lubricating oil filter, refer to section 13.5.11
- ☐ Fuel filter, refer to section 13.5.12
- ☐ Coolant filter and inhibitor, refer to section 13.5.13

13.4.4 450 Hours (13,500 miles—21,600 km) Maintenance

Every 450 hours (13,500 miles—21,600 km), the following components must be inspected, serviced, corrected, or replaced as necessary.

- ☐ Tachometer drive, refer to section 13.5.7
- ☐ Air compressor, refer to section 13.5.9
- ☐ Air system, refer to section 13.5.15
- ☐ Exhaust system, refer to section 13.5.16

Likewise, the following components must be replaced every 450 hours (13,500 miles—21,600 km).

- ☐ Lubricating oil, refer to section 13.5.1
- ☐ Lubricating oil filter, refer to section 13.5.11
- ☐ Fuel filter, refer to section 13.5.12
- ☐ Coolant filter and inhibitor, refer to section 13.5.13

13.4.5 600 Hours (18,000 miles—28,800 km) Maintenance

Every 600 hours (18,000 miles—28,800 km), the following components must be inspected, serviced, corrected, or replaced as necessary.

- ☐ Fuel tank, refer to section 13.5.2
- ☐ Tachometer drive, refer to section 13.5.7
- ☐ Air compressor, refer to section 13.5.9
- ☐ Air system, refer to section 13.5.15
- ☐ Exhaust system, refer to section 13.5.16
- ☐ Engine (steam clean), refer to section 13.5.17
- ☐ Radiator and air-to-air charge cooler, refer to section 13.5.18
- ☐ Oil pressure, refer to section 13.5.19
- ☐ Battery charging alternator, refer to section 13.5.20
- ☐ Engine and transmission mounts, refer to section 13.5.21
- ☐ Crankcase pressure, refer to section 13.5.22
- ☐ Thermostats and seals, refer to section 13.5.24
- ☐ Crankcase breather, refer to section 13.5.25

Likewise, the following components must be replaced every 600 hours (18,000 miles—28,800 km).

☐ Lubricating oil, refer to section 13.5.1
☐ Lubricating oil filter, refer to section 13.5.11
☐ Fuel filter, refer to section 13.5.12
☐ Coolant filter and inhibitor, refer to section 13.5.13

13.4.6 750 Hours (22,500 miles—36,000 km) Maintenance

Every 750 hours (22,500 miles—36,000 km), the following components must be inspected, serviced, corrected, or replaced as necessary.

☐ Cooling system, refer to section 13.5.4
☐ Tachometer drive, refer to section 13.5.7
☐ Air compressor, refer to section 13.5.9
☐ Air system, refer to section 13.5.15
☐ Exhaust system, refer to section 13.5.16

Likewise, the following components must be replaced every 750 hours (22,500 miles—36,000 km).

☐ Lubricating oil, refer to section 13.5.1
☐ Lubricating oil filter, refer to section 13.5.11
☐ Fuel filter, refer to section 13.5.12
☐ Coolant filter and inhibitor, refer to section 13.5.13

13.4.7 900 Hours (27,000 miles—43,200 km) Maintenance

Every 900 hours (27,000 miles—43,200 km), the following components must be inspected, serviced, corrected, or replaced as necessary.

☐ Fuel tank, refer to section 13.5.2
☐ Tachometer drive, refer to section 13.5.7
☐ Air compressor, refer to section 13.5.9
☐ Air system, refer to section 13.5.15
☐ Exhaust system, refer to section 13.5.16
☐ Engine (steam clean), refer to section 13.5.17
☐ Radiator and air-to-air charge cooler, refer to section 13.5.18
☐ Battery charging alternator, refer to section 13.5.20

Likewise, the following components must be replaced every 900 hours (27,000 miles—43,200 km).

☐ Lubricating oil, refer to section 13.5.1
☐ Lubricating oil filter, refer to section 13.5.11
☐ Fuel filter, refer to section 13.5.12
☐ Coolant filter and inhibitor, refer to section 13.5.13

13.4.8 1,050 Hours (31,500 miles—50,400 km) Maintenance

Every 1,050 hours (31,500 miles—50,400 km), the following components must be inspected, serviced, corrected, or replaced as necessary.

☐ Tachometer drive, refer to section 13.5.7
☐ Air compressor, refer to section 13.5.9
☐ Air system, refer to section 13.5.15
☐ Exhaust system, refer to section 13.5.16
☐ Fan Hub, refer to section 13.5.23

Likewise, the following components must be replaced every 1,050 hours (31,500 miles—50,400 km).

☐ Lubricating oil, refer to section 13.5.1
☐ Lubricating oil filter, refer to section 13.5.11
☐ Fuel filter, refer to section 13.5.12
☐ Coolant filter and inhibitor, refer to section 13.5.13

13.4.9 1,200 Hours (36,000 miles—57,600 km) Maintenance

Every 1,200 hours (36,000 miles—57,600 km), the following components must be inspected, serviced, corrected, or replaced as necessary.

☐ Fuel tank, refer to section 13.5.2
☐ Tachometer drive, refer to section 13.5.7
☐ Air compressor, refer to section 13.5.9
☐ Air system, refer to section 13.5.15
☐ Exhaust system, refer to section 13.5.16
☐ Engine (steam clean), refer to section 13.5.17
☐ Radiator and air-to-air charge cooler, refer to section 13.5.18
☐ Oil pressure, refer to section 13.5.19
☐ Battery charging alternator, refer to section 13.5.20
☐ Engine and transmission mounts, refer to section 13.5.21
☐ Crankcase pressure, refer to section 13.5.22
☐ Thermostats and seals, refer to section 13.5.24
☐ Crankcase breather, refer to section 13.5.25

Likewise, the following components must be replaced every 1,200 hours (36,000 miles—57,600 km).

☐ Lubricating oil, refer to section 13.5.1
☐ Lubricating oil filter, refer to section 13.5.11
☐ Fuel filter, refer to section 13.5.12
☐ Coolant filter and inhibitor, refer to section 13.5.13

13.4.10 1,350 Hours (40,500 miles—64,800 km) Maintenance

Every 1,350 hours (40,500 miles—64,800 km), the following components must be inspected, serviced, corrected, or replaced as necessary.

☐ Tachometer drive, refer to section 13.5.7
☐ Air compressor, refer to section 13.5.9
☐ Air system, refer to section 13.5.15
☐ Exhaust system, refer to section 13.5.16

Likewise, the following components must be replaced every 1,350 hours (40,500 miles—64,800 km).

☐ Lubricating oil, refer to section 13.5.1
☐ Lubricating oil filter, refer to section 13.5.11
☐ Fuel filter, refer to section 13.5.12
☐ Coolant filter and inhibitor, refer to section 13.5.13

13.4.11 1,500 Hours (45,000 miles—72,000 km) Maintenance

Every 1,500 hours (45,000 miles—72,000 km), the following components must be inspected, serviced, corrected, or replaced as necessary.

☐ Fuel tank, refer to section 13.5.2
☐ Cooling system, refer to section 13.5.4
☐ Tachometer drive, refer to section 13.5.7
☐ Air compressor, refer to section 13.5.9
☐ Air system, refer to section 13.5.15
☐ Exhaust system, refer to section 13.5.16
☐ Engine (steam clean), refer to section 13.5.17
☐ Radiator and air-to-air charge cooler, refer to section 13.5.18
☐ Battery charging alternator, refer to section 13.5.20

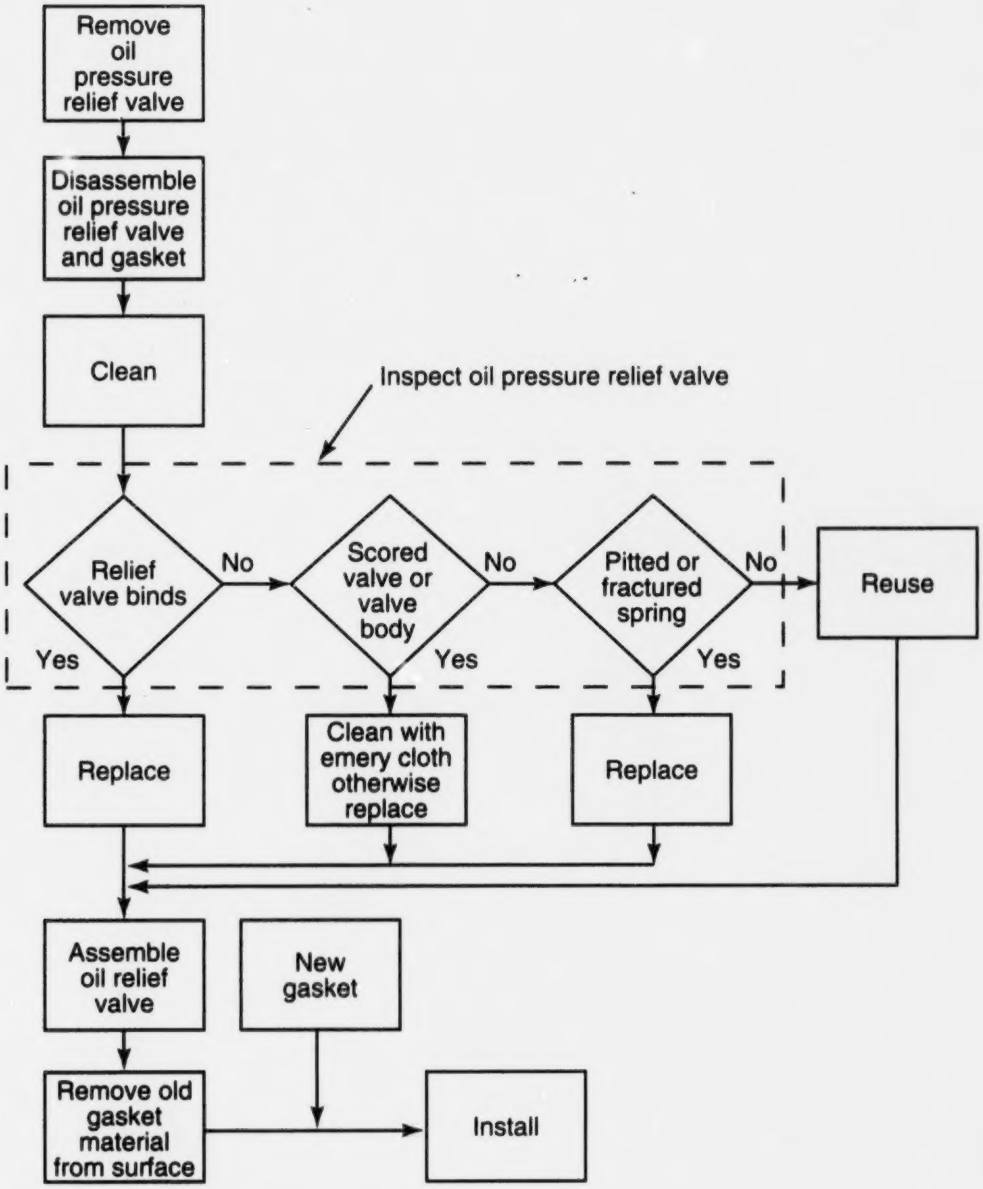
Likewise, the following components must be replaced every 1,500 hours (45,000 miles—72,000 km).

☐ Lubricating oil, refer to section 13.5.1
☐ Lubricating oil filter, refer to section 13.5.11
☐ Fuel filter, refer to section 13.5.12
☐ Coolant filter and inhibitor, refer to section 13.5.13

Courtesy of Detroit Diesel Corporation

Student Supplement 4—Example of Flowchart Style Maintenance Troubleshooting Chart

Flowchart for Repair or Replacement of Oil Pressure Relief Valve


Remove oil pressure relief valve
Disassemble oil pressure relief valve and gasket
Clean
Inspect oil pressure relief valve
Relief valve binds
No
Scored valve or valve body
No
Pitted or fractured spring
No
Reuse
Yes
Yes
Yes
Replace
Clean with emery cloth otherwise replace
Replace
Assemble oil relief valve
New gasket
Remove old gasket material from surface
Install

Courtesy of Detroit Diesel Corporation

1080

Student Supplement 5—Example of Narrative Style Maintenance Troubleshooting Chart

P-101: Engine Will Not Crank

Probable root causes:

NOTE: This is NOT an EUI system problem.

- Batteries
- Starting circuit problem (in machine wiring)
- Starter solenoid
- Starter motor
- Starter ring gear
- Transmission or Power Take-Off problem
- Hydraulic cylinder lock
- Internal engine problem

Perform the following tests in order:

NOTE: For details of tests below, see Testing and Adjusting section of Systems Operation, Testing & Adjusting, 3508 EUI Engine, SENR5589.

1. Charge batteries (See Special Instruction SEH7633, for Battery Test Procedure).
2. Load test batteries (See Special Instruction SEH9249, for Use Of 4C-4911 Battery Load Tester).
3. Check machine wiring to starter solenoid.
4. Inspect starter cables for damage or loose connections.
5. Remove and clean starter cables and connections if corroded.
6. Test starter solenoid operation. Refer to Systems Operation, Testing & Adjusting, 3508 EUI Engine, SENR5589.
7. Test starter motor operation. Refer to Systems Operation, Testing & Adjusting, 3508 EUI Engine, SENR5589.
8. Check for fluid in cylinder by removing individual nozzles.
9. Remove and inspect starter ring gear for damage.
10. Disassemble engine to inspect internal components that may be seized, broken, out of alignment, etc. Refer to Disassembly & Assembly, 3508 EUI Engine, SENR5192.

© Caterpillar Inc. Used with permission

P-102 Engine Cranks But Will Not Start

Probable root causes:

- User Defined Shutdown active
- Crank W/O Inject active
- Electrical power supply to ECM
- Fuel supply or injector priming problem
- Electrical connections to the fuel injector solenoids
- Engine Speed/Timing Signal
- ECM or personality Module
- Combustion problem

Perform the following tests in order:

1. Make sure the User Defined Shutdown input is not active. If the User Defined Shutdown input was active then determine the reason for activation of the input. After correcting the problem turn the keyswitch OFF for at least 15 seconds before trying to restart the engine. Use the ECAP tool "Display Status" screen number 4 to verify the condition of the input.
2. Make sure the Crank W/O Inject inputs are not active. If the Crank W/O Inject input is active then change the connector J24/P24 back to lug HHH.The engine may be started at anytime. Use the ECAP tool "Display Status" screen number 4 to verify the correct position of plug J24/P24.
3. P-503: Electrical Power Supply Functional Test.
4. If ECAP does not communicate with ECM, refer to P-523: CAT Data Link in this manual.
5. Check Fuel Pressure. Also, check that fuel system is primed and that fuel supply and return lines are not restricted. In temperatures below 0°C (32°F), check for congealed fuel (wax).
6. Check that J3/P3 thru J10/P10 (injector connectors) are installed correctly. Do P-515: Injector Solenoid Test, Step 1, as a quick check to confirm that the ECM can energize the injector solenoids.
7. P-514: Engine Speed/Timing Sensor Functional Test. Also be sure that the timing reference gear is installed correctly [if the gear was installed backward (flipped over) during reassembly, the engine will not run]. Also the reference gear must be properly keyed to the camshaft by means of the locating dowel.
8. Check for combustion problems (too cold or mechanical problem).

Objective 9

Assignment Sheet 1—Determine Maintenance Needed for Given Situations

Name ______________________________ Overall Rating __________

Date ______________________________

Evaluation Criteria	Rating
• Correct supplements used for information	______
• Appropriate maintenance recommended	______
• Written descriptions are clear and concise	______
• Written descriptions are neat	______

Basic Skills

Reading Writing Critical Thinking Employability

Directions

In each of the practice situations below, read the description of vehicle service/usage. Then, use the information in Student Supplements 1–3 to answer the questions concerning required maintenance.

Situation #1 (Use Student Supplement 1)

The owner of a Kenworth conventional tractor pulls into your shop and tells you "it's time for an oil change." The vehicle log provides the following information:

Engine type	Detroit Diesel Series 60
Vehicle mileage	145,000 miles
Elapsed time since last service:	2 months
Miles traveled since last service:	13,000 miles
Last service performed:	Oil/oil filter service Filter inspection Clutch inspection/adjustment

As you check out the truck, you notice the following:

- Steering axle tires cupped and worn along the inner edges.
- Engine is covered with grime. There are signs of spilled oil along the sides of the block.
- Flexible duct near the air filter has a 2" cut near the clamp.
- Radiator core is partially clogged with dead bugs.
- Oil pressure at idle with engine warm is 12 psi.

What maintenance tasks would you perform? Why? Be specific.

Situation #2 (Use Student Supplement 2)

You are part of a service crew called out on-site to handle the maintenance on several pieces of construction equipment. You are responsible for checking out a Caterpillar D11N dozer. Maintenance records show the following:

Engine type:	Caterpillar 3516
Total vehicle hours:	248
Hours since last maintenance:	48 hours
Last service performed:	50 hr/weekly service

As you check out this piece of equipment, you notice the following:

- Engine, undercarriage, and cab are very clean, despite dusty operating conditions.
- This machine has had the same operator since new, three months ago.

What maintenance tasks would you perform? Why? Be specific.

Situation #3 (Use Student Supplement 3)

You are part of a service crew called out on-site to handle the maintenance on a 50kva stand-by generator. No maintenance records are available.

Engine type:	Detroit Series 60
Total vehicle hours:	1210 (According to hourmeter)
Hours since last maintenance:	Unknown
Last service performed:	Unknown

As you check out this piece of equipment, you notice the following:

- Engine and genset are dusty, but no obvious damage or fluid leaks are visible.
- There is no maintenance history available. The supervisor in charge of the facility tells you, "We had some guy out here last month to work on it. I'm not sure what he did. I can't find the invoice. You guys take care of whatever scheduled maintenance it needs. OK?"

What maintenance tasks would you perform? Why? Be specific.

1084

Objective 10

Assignment Sheet 2—Interpret Maintenance Troubleshooting Charts

Name ______________________ Overall Rating __________

Date ______________________

Evaluation Criteria	**Rating**
• Correct supplements used for information	______
• Answers are correct	______
• Written descriptions are clear and concise	______
• Written descriptions are neat	______

Basic Skills

Reading Writing Critical Thinking

Directions

To answer the questions in each section below, refer to Student Supplements 4 and 5.

Part 1—Repair/Replacement of Oil Pressure Relief Valve (Use Student Supplement 4)

a. Write three steps that must be taken before the valve can be inspected.

- ______________________________
- ______________________________
- ______________________________

b. Your inspection shows the valve body to be scored. What step is taken next?

____

c. What two conditions would require replacement of the valve?

- ______________________________
- ______________________________

d. Is old gasket material removed before or after the relief valve is reassembled? ______________

Assignment Sheet 2

Part 2—P101: Engine Will Not Crank (Use Student Supplement 5)

a. List the eight probable root causes:

- ______________________________
- ______________________________
- ______________________________
- ______________________________
- ______________________________
- ______________________________
- ______________________________
- ______________________________

b. To load test the batteries, what special instruction should be referenced? ______________

c. What piece of equipment should be used to load test the batteries? Be specific. ______________

d. How do you check for water or other fluids in the cylinders?

____

e. What must be done to inspect seized or broken internal parts?

____

Objective 11

Job Sheet 1—Inspect Engine Coolant Level and Condition

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Correct procedures identified for assigned vehicle	______
• Procedures completed correctly	______
• Proper tools used correctly	______
• Safety precautions observed	______
• Installed equipment functions correctly	______
• Serviced equipment meets specifications	______
• Clean-up and follow-up actions adequate	______

Basic Skills

Reading Writing Critical Thinking Employability

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, Equipment, and Materials

- Technician's common hand tools
- Appropriate engine service manual
- Job ticket or work order—one is included or use appropriate one provided at your facility
- Recommended coolant service kit for assigned cooling system
- Flashlight
- Engine to be worked on
- Others—as recommended by instructor and equipment service manual

Guidelines

☐ 1. Ensure that engine is stopped before beginning this procedure.

☐ 2. Relieve system pressure before removing radiator cap.

☐ 3. Clean up any spilled antifreeze solution—it makes metal and concrete surfaces very slippery.

Procedure

☐ 1. Locate and follow the appropriate procedure in the service manual.

☐ 2. Complete the accompanying job ticket with all pertinent information.

☐ 3. Set parking brake, remove ignition key, and chock wheels.

☐ 4. Remove the radiator cap and withdraw a suitable amount of coolant.

☐ 5. Use kit as directed to check for appropriate levels of coolant levels. Be sure to check nitrate level, pH, and freezing point, as well as any others recommended. Record findings on job ticket.

☐ 6. Compare levels with manufacturer's recommendations. Record on job ticket.

☐ 7. Add supplemental coolant additives as directed. Record on job ticket.

☐ 8. If coolant level is low, add approved coolant to the system until level is correct.

☐ 9. Turn in job ticket when finished.

☐ 10. Clean work area and return tools and materials to proper storage.

Evaluator's Comments: ______________________________

____

____

1038

Job Sheet 1

PARTS LIST

QTY.	PARTS/MATERIALS	PRICE	
TOTAL PARTS/MATERIALS			

SPECIFICATIONS CHECKED

School/Work Name ____________________

Address ____________________

Phone # ____________________

Date In __________

Date Out __________

JOB TICKET

Customer Name ____________________

Customer Address ____________________

Customer Phone # ____________________

Vehicle/Equip.	Make & Model	License #/Motor #/Serial #	Speedometer

Condition reported by customer/service requested: ____________________

Services/repairs made: ____________________

LABOR	

Customer Authorization

I, the undersigned, have reviewed the required service and parts estimates and authorize this maintenance to be pêrformed with the understanding that I will be notified prior to the performance of any work that significantly exceeds those estimates in time or cost.

____________________ Date __________

Technician __________

Supervisor __________

1090

1069

Objective 12

Job Sheet 2—Pressure Test Coolant System and Radiator Cap

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Correct procedures identified for assigned vehicle	______
• Procedures completed correctly	______
• Proper tools used correctly	______
• Safety precautions observed	______
• Installed equipment functions correctly	______
• Serviced equipment meets specifications	______
• Clean-up and follow-up actions adequate	______

Basic Skills

Reading Writing Critical Thinking Employability

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, Equipment, and Materials

- Technician's common hand tools
- Appropriate engine service manual
- Job ticket or work order—one is included or use appropriate one provided at your facility
- Safety glasses
- Radiator pressure tester with cap adapter
- Engine to be worked on
- Others—as recommended by instructor and equipment service manual

Guidelines

☐ 1. Ensure that engine is stopped before beginning this procedure.

☐ 2. Relieve system pressure before removing radiator cap.

☐ 3. Clean up any spilled antifreeze solution—it makes metal and concrete surfaces very slippery.

Procedure

☐ 1. Locate and follow the appropriate procedure in the service manual.

☐ 2. Complete the accompanying job ticket with all pertinent information.

☐ 3. Set parking brake, remove ignition key, and chock wheels.

☐ 4. Remove the radiator cap. Make sure the coolant level is correct and that the radiator filler neck is clean and free of burrs or dents.

☐ 5. Install the tester in the filler neck, being sure to seat it squarely and completely.

☐ 6. Pressurize the system with the hand pump while watching the gauge on the tester.

Note: Do not exceed the manufacturer's recommended pressure. Over-pressurizing th radiator will damage and deform the core and cause seam leaks.

☐ 7. Observe the tester's pressure gauge; it should be holding steady.

☐ 8. Visually inspect all coolant hoses for signs of seepage or swelling.

☐ 9. Slowly release the pressure, and remove the tester from the radiator.

☐ 10. Using the cap adapter, connect the radiator cap to the tester.

☐ 11. Repeat steps #6 and #7.

☐ 12. Release the pressure. If the cap checks good, reinstall it; if bad, replace it.

☐ 13. Turn in job ticket when finished.

☐ 14. Clean work area and return tools and materials to proper storage.

Evaluator's Comments: ____

____

____

1082

Job Sheet 2

PARTS LIST

QTY.	PARTS/MATERIALS	PRICE	
TOTAL PARTS/MATERIALS			

SPECIFICATIONS CHECKED

School/Work Name ______________________

Address ______________________

Phone # ______________________

Date In ____________

Date Out ____________

JOB TICKET

Customer Name ______________________

Customer Address ______________________

Customer Phone # ______________________

Vehicle/Equip.	Make & Model	License #/Motor #/Serial #	Speedometer

Condition reported by customer/service requested: ______________________

Services/repairs made: ______________________

LABOR	

Customer Authorization

I, the undersigned, have reviewed the required service and parts estimates and authorize this maintenance to be performed with the understanding that I will be notified prior to the performance of any work that significantly exceeds those estimates in time or cost.

______________________ Date ____________

Technician ____________

Supervisor ____________

Objective 13

Job Sheet 3—Take Oil Sample, and Change Oil and Filter(s)

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Correct procedures identified for assigned vehicle	______
• Procedures completed correctly	______
• Proper tools used correctly	______
• Safety precautions observed	______
• Installed equipment functions correctly	______
• Serviced equipment meets specifications	______
• Clean-up and follow-up actions adequate	______

Basic Skills

Reading Writing Critical Thinking Employability

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, Equipment, and Materials

- Technician's common hand tools
- Appropriate engine service manual
- Job ticket or work order—one is included or use appropriate one provided at your facility
- Safety glasses
- Replacement filter(s)
- Correct type and amount of replacement oil
- Funnel and/or spout
- Container to catch waste oil
- Oil filter wrench
- Engine to be worked on
- Others—as recommended by instructor and equipment service manual

Guidelines

☐ 1. Make sure that all funnels and spouts are clean.

☐ 2. Prelube replacement filters by filling them with clean oil before installation.

☐ 3. Dispose of waste oil and filter elements in accordance with EPA guidelines.

☐ 4. Place all oily shop towels in approved airtight storage containers.

Job Sheet 3

Procedure

☐ 1. Locate and follow the appropriate procedure in the service manual.

☐ 2. Complete the accompanying job ticket with all pertinent information.

☐ 3. Set parking brake, remove ignition key, and chock wheels.

☐ 4. Thoroughly clean the area around the engine drain plug and oil filter housing.

☐ 5. Visually inspect the engine for signs of oil leakage. Note these on the job ticket.

☐ 6. After performing the sampling procedure, be sure that the label is accurately filled out and attached to the sample bottle.

☐ 7. After removing filter/filter element, wipe all mating surface carefully with a clean shop towel.

☐ 8. Lightly oil O-rings or filter base gaskets before installing. Closely follow the filter manufacturer's tightening recommendations.

☐ 9. Add oil or refill crankcase as required.

☐ 10. Start the engine and watch carefully for oil pressure. If there is no oil pressure indication within 15 seconds of startup, shut the engine down and find out why.

☐ 11. Allow the engine to run for several minutes; check for leaks.

☐ 12. Shut down the engine. Wait a minute, then check the oil level. Add oil if necessary.

☐ 13. Turn in job ticket when finished.

☐ 14. Clean work area and return tools and materials to proper storage.

Evaluator's Comments: ____________________

____

____

1056

PARTS LIST

QTY.	PARTS/MATERIALS	PRICE	
TOTAL PARTS/MATERIALS			

SPECIFICATIONS CHECKED

School/Work Name ____________________

Address ____________________

Phone # ____________________

Date In ____________

Date Out ____________

JOB TICKET

Customer Name ____________________

Customer Address ____________________

Customer Phone # ____________________

Vehicle/Equip.	Make & Model	License #/Motor #/Serial #	Speedometer

Condition reported by customer/service requested: ____________________

Services/repairs made: ____________________

LABOR	

Customer Authorization

I, the undersigned, have reviewed the required service and parts estimates and authorize this maintenance to be performed with the understanding that I will be notified prior to the performance of any work that significantly exceeds those estimates in time or cost.

____________________ Date ____________

Technician ____________

Supervisor ____________

Objective 14

Job Sheet 4—Inspect and Test Indicator System Components

Name ____________________ Attempt Number ________

Date ____________________ Overall Rating ________

Evaluation Criteria	Rating
• Correct procedures identified for assigned vehicle	______
• Procedures completed correctly	______
• Proper tools used correctly	______
• Safety precautions observed	______
• Installed equipment functions correctly	______
• Serviced equipment meets specifications	______
• Clean-up and follow-up actions adequate	______

Basic Skills

Reading Writing Mathematics Critical Thinking Employability

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, Equipment, and Materials

- Technician's common hand tools
- Appropriate engine service manual
- Job ticket or work order—one is included or use appropriate one provided at your facility
- Vehicle with operational instruments and engine
- Multimeter
- Shop oil pressure and temperature gauges
- Flashlight
- Shop towels
- Vehicle and engine to be worked on
- Others—as recommended by instructor and equipment service manual

Guidelines

☐ 1. Clean oil line fittings before disconnecting. Cap all open lines.

☐ 2. Take care not to accidentally ground power circuits. This results in blown fuses and possible damage to electrical components.

☐ 3. When reconnecting electrical components, use a small amount of silicon dielectric grease on the connector pins.

Job Sheet 4

Procedure

☐ 1. Locate and follow the appropriate procedure in the service manual.

☐ 2. Complete the accompanying job ticket with all pertinent information.

☐ 3. Set parking brake, remove ignition key, and chock wheels.

☐ 4. Visually inspect engine sensors for signs of leakage.

☐ 5. Visually inspect wiring for fraying or binding against metal edges.

☐ 6. Use hand-held shop gauges to verify accuracy of the vehicle gauges.

☐ 7. List pressure readings found, as well as manufacturer's recommendations.

	Oil Pressure Idle	**1500 RPM**	**2100 RPM**
Manufacturer's recommended readings			
Master gauge readings			
Vehicle gauge readings			

☐ 8. When you have completed your work, have your instructor verify your work and initial this sheet.

Instructor's initials ______________

☐ 9. Turn in job ticket when finished.

☐ 10. Clean work area and return tools and materials to proper storage.

Evaluator's Comments: ______________________________

____

____

1101

PARTS LIST

QTY.	PARTS/MATERIALS	PRICE	
TOTAL PARTS/MATERIALS			

SPECIFICATIONS CHECKED

School/Work Name ______________________

Address ______________________

Phone # ______________________

Date In ____________

Date Out ____________

JOB TICKET

Customer Name ______________________

Customer Address ______________________

Customer Phone # ______________________

Vehicle/Equip.	Make & Model	License #/Motor #/Serial #	Speedometer

Condition reported by customer/service requested: ______________________

____

Services/repairs made: ______________________

	LABOR	

Customer Authorization

I, the undersigned, have reviewed the required service and parts estimates and authorize this maintenance to be performed with the understanding that I will be notified prior to the performance of any work that significantly exceeds those estimates in time or cost.

______________________ Date ____________

Technician ____________

Supervisor ____________

Objective 15

Job Sheet 5—Perform a Daily Preventive Maintenance Check

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Correct procedures identified for assigned vehicle	______
• Procedures completed correctly	______
• Proper tools used correctly	______
• Safety precautions observed	______
• Installed equipment functions correctly	______
• Serviced equipment meets specifications	______
• Clean-up and follow-up actions adequate	______

Basic Skills

Reading Writing Critical Thinking Employability

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, Equipment, and Materials

- Technician's common hand tools
- Appropriate service manual
- Job ticket or work order—one is included or use appropriate one provided at your facility
- Appropriate preventive maintenance chart
- Lubricants
- Coolant
- Safety glasses
- Assigned engine/vehicle/equipment to be worked on
- Others—as recommended by instructor and equipment service manual

Guidelines

- Ensure that starting power is disconnected before beginning this procedure.
- Spilled engine fluids cause hazardous footing. Clean up all spills as soon as they happen.

Procedure

☐ 1. Locate and follow the appropriate procedure in the service manual.

☐ 2. Complete the accompanying job ticket with all pertinent information.

☐ 3. Set parking brake, remove ignition key, and chock wheels.

☐ 4. Check with operator to verify any complaints. Note any problems that need to be corrected today.

☐ 5. Review past maintenance documents. Note any deficiencies that need to be corrected today.

☐ 6. Check engine lube oil.

  ☐ a. Make sure engine is stopped and level.

  ☐ b. If the engine has been running, wait approximately 20 minutes before checking. This allows time for the oil to completely drain back into the crankcase.

  ☐ c. If oil is needed, be sure to add the proper type and grade to maintain the correct level on the dipstick.

  ☐ d. With engine running at operating temperature, check oil pressure.

☐ 7. Check fuel tank(s).

  ☐ a. Keep tanks full to minimize condensation.

  ☐ b. Drain the fuel filters or fuel/water separators. Check the drained fuel for traces of water.

☐ 8. Check fuel lines, linkages, and fasteners.

  ☐ a. Check hoses for leaks, cracks, and splits.

  ☐ b. Check all fittings, clamps, and ties.

  ☐ c. Be sure that hoses are not resting on or touching shafts, couplings, hot surfaces, or sharp edges.

  ☐ d. Check all fasteners for condition and tightness.

  ☐ e. Check mechanical linkage for wear or binding.

☐ 9. Check cooling system.

  ☐ a. Check coolant level.

  ☐ b. Check for leaks around radiator seams.

  ☐ c. Check underneath the engine for puddles or wet spots.

- ☐ d. Check belts for condition and tightness.
- ☐ e. Inspect the radiator core for damaged fins, debris, or leaks.

☐ 10. Check turbocharger.

- ☐ a. Check the turbocharger mounting for tightness.
- ☐ b. Check the intake and exhaust ducting and connections for signs of leakage.
- ☐ c. With the engine running, check for excessive noise and vibration.

☐ 11. Start and run the engine. Perform the following "running/driving" checks, and listen for unusual noises or conditions:

- ☐ a. Operation of gear shift
- ☐ b. Operation of all instrument gauges, including pressures, speedometer, temperatures, and charging system
- ☐ c. Operation of electronic engine controls
- ☐ d. Operation of road speed governor
- ☐ e. Operation of cruise control
- ☐ f. Evidence of excessive exhaust smoke
- ☐ g. General ease of handling and overall operation
- ☐ h. Performance of service brakes

☐ 12. Have instructor check your work.

☐ 13. Turn in job ticket when finished.

☐ 14. Clean work area and return tools and materials to proper storage.

Evaluator's Comments: ______________________________

____

____

PARTS LIST

QTY.	PARTS/MATERIALS	PRICE	
TOTAL PARTS/MATERIALS			

SPECIFICATIONS CHECKED

School/Work Name ____________________

Address ____________________

Phone # ____________________

Date In __________

Date Out __________

JOB TICKET

Customer Name ____________________

Customer Address ____________________

Customer Phone # ____________________

Vehicle/Equip.	Make & Model	License #/Motor #/Serial #	Speedometer

Condition reported by customer/service requested: ____________________

Services/repairs made: ____________________

LABOR	

Customer Authorization

I, the undersigned, have reviewed the required service and parts estimates and authorize this maintenance to be performed with the understanding that I will be notified prior to the performance of any work that significantly exceeds those estimates in time or cost.

____________________ Date __________

Technician __________

Supervisor __________

Objective 16

Job Sheet 6—Perform a Mileage Prevention Maintenance Check

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Correct procedures identified for assigned vehicle	______
• Procedures completed correctly	______
• Proper tools used correctly	______
• Safety precautions observed	______
• Installed equipment functions correctly	______
• Serviced equipment meets specifications	______
• Clean-up and follow-up actions adequate	______

Basic Skills

Reading Writing Critical Thinking Employability

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, Equipment, and Materials

- Technician's common hand tools
- Appropriate service manual
- Job ticket or work order—one is included or use appropriate one provided at your facility
- Appropriate preventive maintenance chart
- Safety glasses
- Mineral spirits
- Steam cleaner
- Remote electrical test gauge
- Assigned engine/vehicle/equipment to be worked on
- Others—as recommended by instructor and equipment service manual

Guidelines

- Ensure that starting power is disconnected before beginning this procedure.

- Spilled engine fluids cause hazardous footing. Clean up all spills as soon as they happen.

Procedure

☐ 1. Locate and follow the appropriate procedure in the service manual.

☐ 2. Complete the accompanying job ticket with all pertinent information.

☐ 3. Set parking brake, remove ignition key, and chock wheels.

- ☐ 4. Check with operator to verify any complaints. Note any problems that need to be corrected today.
- ☐ 5. Review past maintenance documents. Note any deficiencies that need to be corrected today.

  Note: OEM preventive maintenance charts vary. The following steps are common. Refer to service manual for specific steps.

- ☐ 6. Check fuel tank(s).
  - ☐ a. Use the drain at the bottom of the tank to drain off water and sediment and to pull fuel samples.
  - ☐ b. If unit/tank is to sit idle for an extended period, add a biocide and the correct amount of dry gas.
- ☐ 7. Check cooling system.
  - ☐ a. Check coolant level.
  - ☐ b. Check for leaks around radiator seams.
  - ☐ c. Check underneath the engine for puddles or wet spots.
- ☐ 8. Check tachometer drive.
  - ☐ a. Lubricate the tach drive with all-purpose grease.
  - ☐ b. At temperatures above 30° use No. 2 grade grease; at temperatures below 30°, use No. 1 grade grease.
- ☐ 9. Check drive belts.
  - ☐ a. Check drive belts for cracking, fraying, and overheating.
  - ☐ b. Check pulley grooves for wear and cracking.
  - ☐ c. Check belt tension with a tension gauge, if available. If no gauge is available, adjust the belt so that a firm push with the thumb, at a point halfway between the two pulleys, will depress the belt 1/2–3/4 in.
  - ☐ d. Always replace ALL the belts in a matched set when one is worn.

☐ 10. Check air compressor.

  ☐ a. Remove and clean all air compressor intake parts. Remember to reoil the filter and squeeze it dry before reinstalling it.

  ☐ b. Check the tightness of the air compressor mounting bolts.

☐ 11. Check air system.

  ☐ a. Check exhaust clamps at turbocharger inlet and exhaust for signs of corrosion or leakage.

  ☐ b. Check all air hoses and ducting for punctures, deterioration, or other damage.

  ☐ c. Check all connections for tightness.

☐ 12. Check exhaust system.

  ☐ a. Check all manifold retaining bolts for tightness.

  ☐ b. Check all pipe clamps for tightness.

  ☐ c. Check all joints for signs of exhaust leakage.

  ☐ d. If equipped with an exhaust pipe rain cap, check for proper operation.

☐ 13. Steam clean the engine.

  ☐ a. Protect wiring harnesses.

  ☐ b. Cover/protect the alternator and other electrical/electronic equipment.

☐ 14. Clean the radiator and air-to-air charge cooler.

  ☐ a. Remove bugs and debris from the core fins.

  ☐ b. Clean the exterior of the radiator core with mineral spirits; then dry with compressed air.

☐ 15. Check oil pressure.

  ☐ a. Start the engine and bring it to operating temperature.

- ☐ b. Note the oil pressure at idle; record it on the preventive maintenance form.
- ☐ c. If the engine has only warning lights, connect a remote gauge to get an accurate reading.

☐ 16. Check battery, alternator, and starter.

- ☐ a. Inspect the battery terminals for corrosion and loose connections.
- ☐ b. Inspect alternator terminals for loose connections.
- ☐ c. Check all wiring for signs of fraying insulation.

☐ 17. Check engine and transmission mounts.

- ☐ a. Check all mounting bolts for tightness and wear.
- ☐ b. Check mounting pads for signs of deterioration or separation.

☐ 18. Check crankcase pressure. Record it on the preventive maintenance form.

☐ 19. Check operating temperature. If there is a problem, check thermostat and seals.

☐ 20. Check crankcase breather.

- ☐ a. The crankcase breather is internally mounted inside the engine rocker cover.
- ☐ b. Clean and reinstall the mesh filter; dry with compressed air.

☐ 21. Replace the following:

- ☐ a. Lube oil
- ☐ b. Lube filters
- ☐ c. Fuel filter
- ☐ d. Coolant filter and inhibitor

☐ 22. Have instructor check your work.

☐ 23. Turn in job ticket when finished.

☐ 24. Clean work area and return tools and materials to proper storage.

Evaluator's Comments: ____________________________________

____

____

1113

PARTS LIST

QTY.	PARTS/MATERIALS	PRICE	
TOTAL PARTS/MATERIALS			

SPECIFICATIONS CHECKED

School/Work Name ____________________
Address ____________________
Phone # ____________________

Date In ____________
Date Out ____________

JOB TICKET

Customer Name ____________________
Customer Address ____________________
Customer Phone # ____________________

Vehicle/Equip.	Make & Model	License #/Motor #/Serial #	Speedometer

Condition reported by customer/service requested: ____________________

Services/repairs made: ____________________

LABOR	

Customer Authorization

I, the undersigned, have reviewed the required service and parts estimates and authorize this maintenance to be performed with the understanding that I will be notified prior to the performance of any work that significantly exceeds those estimates in time or cost.

____________________ Date ____________

Technician ____________
Supervisor ____________

Objective 17

Job Sheet 7—Perform an Engine Tune-Up

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation Criteria	Rating
• Correct procedures identified for assigned vehicle	______
• Procedures completed correctly	______
• Proper tools used correctly	______
• Safety precautions observed	______
• Installed equipment functions correctly	______
• Serviced equipment meets specifications	______
• Clean-up and follow-up actions adequate	______

Basic Skills

Reading Writing Critical Thinking Employability

Instructions

When you are ready to perform this task, ask your instructor to observe the procedure and rate your performance using the evaluation criteria.

Tools, Equipment, and Materials

- Technician's common hand tools
- Appropriate service manual
- Job ticket or work order—one is included or use appropriate one provided at your facility
- Appropriate Jake Brake® OEM manual
- Compression tester with adapters
- Radiator and radiator cap pressure tester
- Feeler gauges
- Torque wrench
- Safety glasses
- Assigned engine/vehicle/equipment to be worked on
- Others—as recommended by instructor and equipment service manual

Guidelines

- Ensure that starting power is disconnected before beginning this procedure.

- Do not mix Jake Brake® mounting bolts with rocker arm shaft mounting bolts. The two can be very similar in appearance. Should this occur, note that the Jake Brake® bolts have the Jacobs logo (circled "J") and the bolt length (110 mm) marked on the head.

Procedure

☐ 1. Locate and follow the appropriate procedure in the service manual.

☐ 2. Complete the accompanying job ticket with all pertinent information.

☐ 3. Set parking brake, remove ignition key, and chock wheels.

☐ 4. Clean and remove valve cover(s).

☐ 5. Inspect valve components.

☐ 6. Check and adjust:

  ☐ a. Valve clearance

  Note: If equipped with Jake Brakes®, it may be necessary to remove the units.

  ☐ b. Injector height/injector rocker arm clearance

  ☐ c. Jake Brake® slave piston lash

☐ 7. If required, check the injectors.

  ☐ a. Inspect for signs of carbon build-up or mechanical damage.

  ☐ b. Clean the injector hole in the cylinder head.

  ☐ c. Clean injectors and test pop-off pressure.

  Note: Electronic unit injectors are not designed to be disassembled. If the injector is defective, it must be replaced as a unit.

☐ 8. Inspect the fuel injector tubes; replace as needed.

☐ 9. Check injector pump timing; adjust as needed.

☐ 10. Have instructor check your work.

☐ 11. Turn in job ticket when finished.

☐ 12. Clean work area and return tools and materials to proper storage.

Evaluator's Comments: ______________________________

____

____

1117

Job Sheet 7

PARTS LIST

QTY.	PARTS/MATERIALS	PRICE	
TOTAL PARTS/MATERIALS			

SPECIFICATIONS CHECKED

School/Work Name ______________________

Address ______________________

Phone # ______________________

Date In ____________

Date Out ____________

JOB TICKET

Customer Name ______________________

Customer Address ______________________

Customer Phone # ______________________

Vehicle/Equip.	Make & Model	License #/Motor #/Serial #	Speedometer

Condition reported by customer/service requested: ______________________

Services/repairs made: ______________________

LABOR	

Customer Authorization

I, the undersigned, have reviewed the required service and parts estimates and authorize this maintenance to be performed with the understanding that I will be notified prior to the performance of any work that significantly exceeds those estimates in time or cost.

______________________ Date ____________

Technician ____________

Supervisor ____________

U.S. Department of Education
Office of Educational Research and Improvement (OERI)
National Library of Education (NLE)
Educational Resources Information Center (ERIC)

ERIC®

NOTICE

Reproduction Basis

☒ This document is covered by a signed "Reproduction Release (Blanket)" form (on file within the ERIC system), encompassing all or classes of documents from its source organization and, therefore, does not require a "Specific Document" Release form.

☐ This document is Federally-funded, or carries its own permission to reproduce, or is otherwise in the public domain and, therefore, may be reproduced by ERIC without a signed Reproduction Release form (either "Specific Document" or "Blanket").

EFF-089 (3/2000)